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HARVESTING and HANDLING CITRUS FRUITS IN THE GULF STATES



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MATURE CITRUS FRUIT even from the same tree varies in size and appearance. Yet the consumer demands uniformity in size and appearance of fruit as well as in quality.

To meet these requirements the fruit must be picked at the proper degree of ripeness; then the packer must wash, grade, size, and pack his fruit properly. The shipping quality of citrus fruit changes as the season advances as well as from year to year. In order to keep the markets supplied with fresh fruit, shipments must be made in wet and dry weather and in hot and cold weather. The fruit must be handled so as to preserve its attractive appearance and fresh flavor during a 5- to 10-day trip from the packing house to the consumer's home, perhaps a thousand miles away.

A step-by-step description of the processing necessary in delivering citrus fruit in sound condition to consumers in distant States is given in this bulletin. Canned and other processed products also are discussed.

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HARVESTING AND HANDLING CITRUS FRUITS IN THE GULF STATES

By J. R. WINSTON, senior horticulturist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration

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CITRUS fruits made up about 58 percent of the tree fruits grown in the United States in 1947-48. Florida produced about 55 percent of the citrus crop, Texas about 16 percent, and southern Louisiana about 0.2 percent, mostly oranges. From 1919-20 to 1948-49 the citrus crops in Florida and Texas increased as shown in table 1. The increases occurred despite the fact that much of the bearing acreage has not reached the age of full production and extensive tracts of young trees are not bearing. Many acres of citrus are still being planted. In Texas the production of lemons is increasing.

Citrus fruits, like other perishable produce, must be kept sound, fresh looking, and pleasing to the taste until they are eaten. When marketing involves long-distance shipment, as with most citrus fruit consumed in the United States, handling and shipment to market become a highly specialized business. This business is usually conducted by growers' cooperative associations and independent dealers rather than by individual growers. Limes (p. 57) are harvested and handled quite differently from oranges, tangerines, and grapefruit.

TABLE 1.—*Production of citrus fruits in Florida and Texas, by crop years*

[1½ bushels computed as 90 pounds (box) for oranges and tangerines and as 80 pounds (box) for grapefruit and limes]

Crop year	Oranges		Grapefruit		Tangerines	Limes
	Florida	Texas	Florida	Texas	Florida	Florida
	<i>1,000 boxes</i>					
1919-20	7,550	9	5,900	3	450	28
1920-21	8,700	5	5,800	5	700	26
1921-22	7,850	5	6,700	8	550	33
1922-23	10,150	10	7,800	35	750	35
1923-24	13,150	6	8,500	65	550	40
1924-25	10,400	17	8,900	301	900	36
1925-26	9,500	12	7,600	200	700	30
1926-27	10,100	41	8,600	361	900	12
1927-28	8,650	85	7,500	524	850	0
1928-29	15,000	125	11,300	753	1,500	6
1929-30	8,950	261	8,300	1,550	850	8
1930-31	16,800	250	15,800	1,200	2,400	8
1931-32	12,200	520	10,700	2,600	2,000	9
1932-33	14,500	325	11,600	1,440	1,900	10
1933-34	15,900	430	10,900	1,200	2,000	12
1934-35	15,600	650	15,200	2,740	2,000	15
1935-36	15,900	777	11,500	2,780	2,100	12
1936-37	19,100	2,000	18,100	9,630	3,000	45
1937-38	23,900	1,440	14,600	11,840	2,300	70
1938-39	29,900	2,815	23,300	15,670	3,400	95
1939-40	25,600	2,360	15,900	14,400	2,400	95
1940-41	28,600	2,650	24,600	13,650	2,700	80
1941-42	27,200	2,850	19,200	14,500	2,100	150
1942-43	37,200	2,550	27,300	17,510	4,200	175
1943-44	46,200	3,550	31,000	17,710	3,600	190
1944-45	42,800	4,400	22,300	22,300	4,000	250
1945-46	49,800	4,800	32,000	24,000	4,200	200
1946-47	53,700	5,000	29,000	23,300	4,700	170
1947-48	58,400	5,200	33,000	23,200	4,000	170
1948-49	58,300	3,400	30,200	11,300	4,400	200

During the past 30 years there have been great advances in fruit-handling techniques. Some of these are based on rediscovered facts known centuries ago by the Chinese. Despite these advances much improvement is still needed. In the early days of the Florida citrus industry preparation of the fruit for market was the simplest kind of process, consisting merely in picking the fruit, placing it in any available kind of container, and forwarding it by boat to seaboard consuming markets. Later, when railroads were built, small lots went out by local freight. The shipping season was short, uniformity of grade and pack was unheard of, and a russeted orange was often regarded as a variety rather than as a blemished fruit. Now the Florida shipping season normally extends into summer and the preparation of fruit for market involves a number of specialized processes includ-

ing degreening, washing, polishing, grading, sizing, packing, and refrigeration. These processes entail considerable outlay of capital and increase the cost of preparing the fruit for market; but they help to supply the consumer with fruit uniform in appearance, taste, and keeping quality.

Careful handling, as applied to citrus fruit, has only comparatively recently been regarded as essential to successful marketing. Now every successful packing-house operator realizes that the rate of spoilage is increased by rough and improper handling. Decay which develops during shipment or distribution may wipe out all anticipated profits, especially if inadequately protected shipments are not unloaded and consumed promptly and if weather conditions or improper handling at the market favors development of decay. Spoilage can be reduced, however, by careful handling, by the timely application of mild antiseptics, and by refrigeration. The appearance of the fruit and of its container upon arrival at the market determines largely the price the fruit will command.

STANDARDS OF MATURITY

Before citrus fruit can be shipped to market, it must meet the established legal standards of maturity of the State where it is grown and the regulations of the Food and Drug Administration of the Federal Security Agency. In recent years the various citrus-producing States have raised their standards of maturity. These vary somewhat from State to State. In Florida the present standard of legal maturity for oranges and grapefruit designates a "percent break" in rind color, a minimum juice volume, minimum total soluble solids, and a graduated solids-acid ratio for the juice. In general, the higher the solids the lower the required ratio. In Florida, oranges given the color-added, or dye, treatment (p. 20) must be more mature and have a larger volume of juice than natural-color oranges. Tangerines also must have a designated "percent break" in color, contain a minimum total of soluble solids, and have a graduated solids-acid ratio. Tahiti, or Persian, limes must have only a minimum of volume of juice. Texas has generally similar requirements for minimum juice volume, minimum total soluble solids, and solids-acid ratio for oranges and grapefruit. Harvesting of lemons is regulated largely by the size and color of the fruit at time of picking rather than by standards based on the composition of the fruit.

The progressive changes in flavor that take place when oranges and grapefruit pass from the stage of immaturity to that of legal maturity cannot be determined by outward appearance. A deliciously flavored fruit may have a green-colored rind, whereas a sour, unripe one may have lost all its green color, because of varietal characteristics, climatic conditions, or cultural practices. Because of the long blooming period of citrus trees, there may be a difference in the age of fruit of similar size. It would be very easy to ship fruit that is not mature if the official maturity tests were not used. Before the adoption of these standards very acid to sour fruit was often shipped in the earliest part of the season for each variety with consequent bad effects on the market.

By use of the simple chemical tests now required, however, the edibility of the fruit can be ascertained, and the harmful effect upon the market of selling immature fruit can be avoided. These tests, supplemented by quantitative juice measurements in relation to the size of the fruit, are the basis for the legal maturity standards for oranges and grapefruit now enforced by State inspectors. These standards vary somewhat in the different States, but they serve to protect the consumer from being offered very immature fruit and the shipper from the financial losses that occur when immature fruit is sent to market. The "green-fruit laws" are especially applicable during the early part of the shipping season, when legally mature fruit is comparatively scarce and proportionately in greater demand.

To avoid picking immature fruit, which might be condemned and destroyed, an employee of the packing agency, which is generally responsible for picking the crop, usually makes preliminary tests in the grove ahead of the pickers. Although the State inspectors can make their tests at any time during the handling operation, they do not usually make such tests until the fruit is ready to be packed.

The coloring, or degreening, treatment applied to citrus fruit does not ripen or sweeten it in any way; the solids and acids are not appreciably affected by this or any other treatment given after harvest. If the fruit is not legally mature or sufficiently ripe to be relished when eaten at time of harvest, it cannot be brought into such a condition by any known process or treatment. In this respect oranges are different from apples and pears, for example; if oranges are not ripe enough to eat when they are picked they never will be.

ORGANIZATION FOR HANDLING THE CROP

In the picking and packing of citrus fruit, as in all other phases of the industry, there is a great variation in the magnitude of the operations in different units. The labor and methods involved range from the elaborate organization of personnel in the large packing house and cooperative association to that of the small grower and mail-order operator who does his own picking and personally attends to all the procedures necessary in preparing the fruit for market. The methods used, however, are fundamentally the same whether the daily output is 20 carloads or 20 boxes. In this bulletin the working procedure of the larger cooperative packing houses is outlined in some detail. Whenever there is sufficient evidence to warrant recommending particular methods, this fact will be indicated; otherwise the methods in most common use will be described briefly.

The packing-house manager is generally at the head of all of the activities during harvesting operations in the groves and in the packing house. To him all other employees are responsible; in turn he is responsible to the growers who ship through the organization. The manager's chief assistants are the field foreman and the house foreman.

The field foreman supervises all outside work, including selecting and testing the fruit for maturity, estimating the size of the crops, assigning the picking crews, and delivering the fruit in good condition at the packing house.

The house foreman supervises all inside work. If the packing house is small the foreman oversees all the operations; if it is large he

has two or more subforemen or supervising clerks, each assigned to some specific phase of the packing operations, such as receiving the fruit, supervising the coloring rooms, grading, packing, or loading.

HARVESTING OPERATIONS

PICKING

The picking captains aid the field foreman. Each captain supervises the work of an individual crew of pickers, consisting of 6 to 15 men, usually about 12. Several score of men may be employed as pickers by one packing house. They are paid on a piecework basis, at rates that vary with the fruit picked and the kind of picking desired. During some parts of the season, especially the earlier parts for the different varieties, spot picking for color and picking for size are common practices. These limit the pickers to the outside branches of the tree or to particular sizes; generally under these conditions a higher rate per box is paid. Also for picking the smaller fruits a higher rate is paid. The rate usual for grapefruit is about half that for oranges; for tangerines it is about twice that for oranges. Picking is not an easy job, and sometimes it is unpleasant. Weather conditions are often adverse. Although picking is suspended during rainy weather, the men are sometimes caught deep in a grove without protection. In cold or threatening weather the pickers are transported to and from the grove in a canopy-covered truck, which serves as shelter in case of showers during working hours. In mild, clear weather the pickers are transported on open-platform trucks, which also carry the field boxes and ladders. In Texas, harvesting is very largely done by contractors who have their own crews, trucks, and equipment. The packing house deals only with the contractor and pays for the job by the ton or acre.

In picking from trees on which the fruit is beyond the reach of a man on the ground, ordinary round-rung straight ladders, ranging in length from 10 to 36 feet, are commonly used. These are placed carefully against the trees to avoid breaking or injuring the branches.

The fruit is removed from the tree by means of clippers made especially for the purpose or by pulling, that is, picking without the use of clippers. Several kinds of clippers (fig. 1) are available.

In recent years the snub-nosed clipper (fig. 1, *A*) has been the most widely used. Use of this model reduces the danger of "clipper cuts," the term commonly used for the nicking or puncturing of the skin by clippers with long shearing edges. However, by using the older and longer curved scissors model (fig. 1, *B*) faster picking can be done, since the picker can reach out, pull the fruit toward him, and clip it from the stem at the same time. If the snub-nosed clipper is used, the fruit must be held while being picked. Care should be taken to clip the fruit close to the button and leave no protruding stem to injure other fruit in the field box or during washing and polishing. This is not always done; therefore, it is not uncommon to find 20 percent of the fruit with clipper cuts or with long stems which easily injure other fruits. Fruit so damaged is very subject to decay, especially during the winter months.

Pulling of citrus fruit is now a common practice, especially in Florida. During the greater part of the season oranges can be pulled

with but little injury to the rind if the workmen exercise reasonable care. The period when ripe tangerines can be pulled with reasonable safety, however, is very limited. On the other hand, grapefruit, Temple oranges, lemons, and limes can be pulled throughout the shipping season with but slight likelihood of tearing the rind. With fruits that lend themselves to pulling, this method of harvesting appears to have two distinct advantages over clipping, namely economy and reduction in decay. If the calyx points only are removed from the fruit during the pulling operation the liability to stem-end rot is lessened; when all of the stem button is removed, stem-end rot is further reduced. This is the most serious warm-weather decay of citrus grown in the Gulf Coast States. Ordinarily pulled fruit is not so liable

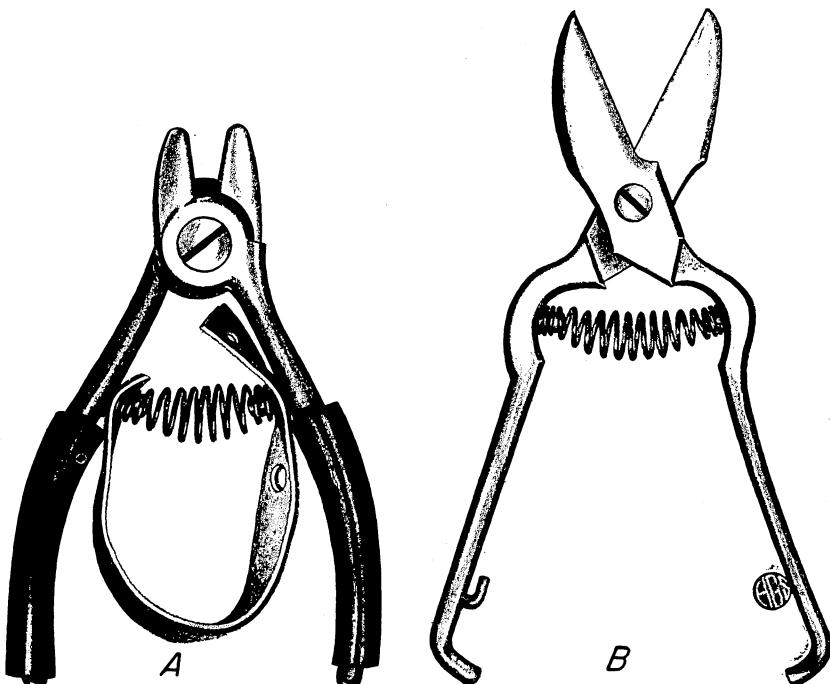


Figure 1.—Popular types of orange clippers. A clipper with a short shearing edge (A) is preferred to one with a longer shearing edge (B), because clipper cuts on the fruit are less likely to be made with the short edge.

to stem-end rot as clipped fruit; but it may be more liable to green mold rot, especially with careless harvesting and handling. To a large extent, therefore, the responsibility for decay rests with the pickers when the pulling method of harvesting is used.

The picker carries a picking bag over his shoulder and hanging at his side. The capacity of this bag is about half a field box. While filling the bag, the picker must be careful not to get it between himself and the ladder, in order to guard against the danger of bruising the fruit. A bruised fruit or one with the skin even slightly cut or broken is very susceptible to decay. The sacks are made so that the bottoms, which are open, can be folded up and hooked, in order to

keep the fruit from falling out before the picker is ready to descend to the ground and empty the fruit into a field box. To empty the fruit the sack is lowered into the box, the fold is unhooked, and the sack is withdrawn. In this way the fruit can be emptied through the bottom without bruising. When picking is good, that is, when the trees are well loaded with fruit, an experienced picker ordinarily can pick approximately 80 boxes of oranges or 120 boxes of grapefruit per day. Pickers and all other workers who handle the fruit should be required to wear gloves to keep their fingernails from injuring the tender skin.

CHOICE OF TYPE OF FIELD BOX

The fruit is usually left in the field boxes until time to put it through the packing-house machinery. These boxes are usually made of cypress, but pine or gum is sometimes used. For durability and lightness cypress is superior but somewhat more expensive. Ordinarily the size of the field boxes is the same for both oranges and grapefruit. The inside dimensions of the standard Florida field box are length, 31½ inches; width, 12 inches; and depth, 13 inches. Standardization of field boxes is important, since many crops are sold on this basis. The box is divided into two compartments by a 5/8-inch center partition, with a handle strip nailed across the head. Sometimes a smaller box, about two-thirds the standard size, is used, and the jumbo, or oversize, box is used for grapefruit. The latter is one-half inch deeper than the standard field box and has a 7/8-inch handle. The word "oversize" is stenciled on all jumbo boxes to indicate that they are not of standard capacity. The jumbo box is too large and heavy for careful handling.

The average weight of an empty cypress standard field box is about 17 pounds. When filled, this box weighs 100 to 120 pounds, depending on the size and quality of the fruit as well as on the fullness of the box. There is a space of approximately one-half inch between the boards on the sides and bottom to prevent water and trash, such as leaves and twigs, from accumulating in the box and to allow free circulation of air around the fruit. The ends are slotted to make convenient hand-holds. Added strength is obtained from the center partition.

The field box generally used in California is sometimes used in the Gulf-coast region. It is somewhat smaller and lighter in weight than the smallest Florida box and is without a center partition.

It is generally agreed that the heavy reinforced field box is best adapted to use in Florida, especially for the large tonnage of grapefruit which must be handled. The lighter, smaller boxes, however, are well adapted to tangerines and limes.

Sometimes it is not possible to obtain a packed box from a standard Florida field box of fruit as brought to the packing house if the crop is not of good quality or the field box is not filled. However, this is generally the objective of the grower or owner of the fruit, particularly of the independent dealer, who often buys fruit by the field box. This desire for a high "pack out," as it is called, which at times amounts to as much as a 10-percent overpack, frequently results in various undesirable practices: the field boxes are filled too full, the fruit is piled on top of the boxes after they are loaded on trucks to be taken to the packing house, or oversize boxes are used. The boxes

are stacked four high on the truck. If they are filled too full, many fruits are bruised and otherwise injured. If fruits are piled on top of the boxes, many are spilled in the process of unloading. The increase in the sale of fruit by weight is discouraging these bad practices, especially the overfilling of field boxes.

HAULING TO THE PACKING HOUSE

In groves where there is insufficient room between the rows of trees for standard trucks, the loaded field boxes are usually hauled out on a low-slung, narrow-gage trailer drawn by a tractor or on a cut-down truck; then they are transferred to standard trucks for hauling to roadside loading platforms or to packing houses. In the reloading, special care is required to prevent bruising or other injury of the fruit.

Only a few years ago practically all the fruit was hauled from groves to packing houses in wagons having a capacity of about 30 boxes. For even the shortest hauls these wagons have now been replaced by motortrucks equipped with dual rear wheels and capable of hauling 60 to 80 or more filled boxes per load and 100 or more empty boxes for the return trip to the groves. For long hauls semitrailer trucks with a capacity of 200 or more filled boxes are commonly used, but larger units with a capacity up to 450 filled boxes are becoming increasingly popular. The semitrailer trucks rarely go into the groves but are loaded at the roadside from smaller trucks or from loading platforms.

PACKING-HOUSE OPERATION AND PROCEDURES

ARRANGEMENT

Although packing houses differ greatly in design, construction, size, and equipment, the same general arrangement and construction are usually followed to facilitate the "straight-line" plan of operation now used so generally in industrial plants. This means carrying the fruit through the various treatments and processes in logical sequence in order to eliminate extra handling and save space. The progress of the fruit is usually from the receiving platform on one side of the house to the shipping platform on the other. A typical floor arrangement is shown in figure 2. Packing houses are rarely constructed with basements in Florida, but basements are more common in Texas.

OPERATION

Upon arrival at the packing house the incoming fruit is checked by the receiving clerk. As it is checked, the fruit is removed from the motortruck onto the receiving platform by means of hand trucks, which carry a full stack (four boxes) at a time. Sometimes the field boxes are transferred by hand from the motortruck, which in this case draws up alongside the receiving platform instead of backing up to it. These boxes are then stacked four or five high and are later moved about by hand trucks.

The first duty of the house foreman is to decide what preliminary treatments are necessary before the fruit is packed or whether the fruit, because of market conditions, should be diverted to the cannery

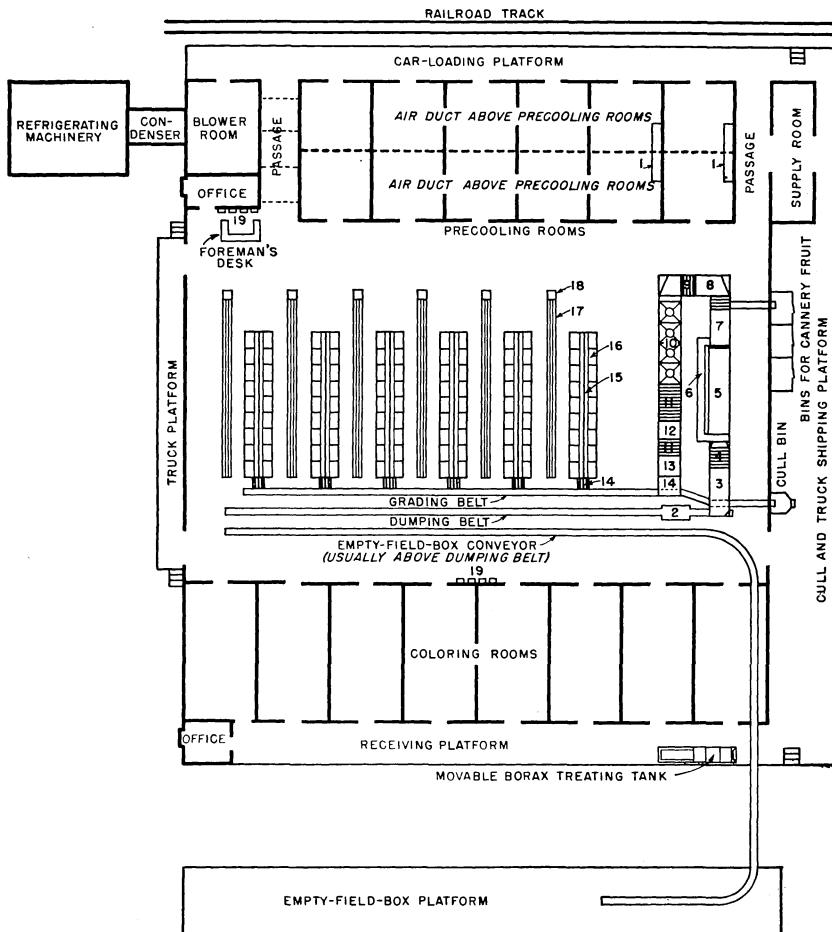


Figure 2.—Floor plan of a typical packing house. 1, Unit cooler (one in each precooling room), which is satisfactorily replacing part of the old precooling system and is less expensive to maintain. 2, Presizer. 3, Soaking tank. 4, Transverse scrubbing brushes. 5, Color-added applicator. 6, Bypass around color-added applicator. 7, Borax tank. 8, Wax-emulsion applicator. 9, Brass-roller water eliminator. 10, Transverse-brush drier. 11, Transverse polishing brushes. 12, Molten- or powdered-wax applicator. 13, Solvent-wax applicator. 14, Fruit-stamping machine. 15, Sizing roller and conveyor. 16, Packers' bins. 17, Packed-box conveyor. 18, Lidding machine. 19, Switchboard.

or other processing plant. The various treatments to which the fruit is subjected in the packing house are described here in the order that generally prevails in commercial practice.

COLORING, OR DEGREENING

In Florida, fruits of several of the early and midseason varieties of orange, including the Parson Brown, Hamlin, Pineapple, and Satsuma, tangerine, and grapefruit reach legal maturity before they develop their maturity color or at least before they reach their full

color. Citrus fruit of any variety growing on heavily foliated trees or in dense shade, such as an inside crop of seedling or Valencia oranges, retains much of its greenness even after full maturity, especially in the southern part of the State and during warm winters.

Valencia oranges develop almost full color in winter but are not harvested until early spring. After new growth starts in the spring, some of these oranges regreen, particularly at the stem end. Many may have failed to degreen and may develop a deeper green color. Even if allowed to remain on the tree until fully ripe, these regreened oranges, as well as those that did not degreen, have the appearance of being immature. Likewise, grapefruit of late-ripening varieties produced in warm locations sometimes regreens or retains a greenish cast in the spring although it is fully mature. Valencia oranges mature earlier in Texas than in Florida and often require no degreening from start to finish of picking.

Since the price that citrus fruit commands generally depends on the appearance, it is highly desirable to make color of fruit correspond to eating quality. With legally mature fruit this can be done by accelerating the natural process of degreening by means of a treatment generally referred to as "coloring." This term, however, is somewhat misleading, since no color is added to that which has already been developed naturally in the fruit. This coloring, or degreening, as described herein is merely a stimulation of the natural processes by which the green pigment is made to disappear rapidly from the rind. By this method, which can be carried out in the packing house, there is produced within a few days a color effect which might otherwise develop only after several weeks on the tree under the most favorable conditions or which might never occur on the tree.

The treatment is a selective decoloring process, because the green pigment which at this time masks the yellow and orange pigments is caused to disappear and whatever shade of orange or yellow is present is generally not affected. Degreening does not in any sense ripen the fruit. If the fruit is immature when harvested, it is equally immature after being degreened. In California this treatment is usually called sweating; with lemons it is also known as forced curing.

In mild, humid weather degreening can be brought about under tents or indoors entirely without special equipment, but the length of time required under such conditions predisposes the fruit to rapid spoilage.

In the more modern packing houses degreening is done in specially designed coloring rooms. All types of such rooms are operated on similar principles whereby the fruit is held in warm, slowly moving air of high relative humidity, into which small quantities of ethylene are introduced. This conditioned air is circulated through the stacks of fruit by fans or blowers. Ethylene is almost odorless when diluted to the very low concentration at which it is used for coloring. It does not impart an unpleasant flavor to the fruit like that sometimes produced by the kerosene fumes previously used.

When ethylene is used, the air-conditioning chambers are frequently located above or below the coloring rooms. They contain all the equipment necessary to heat and humidify the air and introduce the desired amount of ethylene as well as fans to blow the conditioned air into the coloring rooms nearby. The minimum effective concentration of

ethylene has not been accurately determined. It is known, however, that 1 part in 50,000 parts of air if continuously maintained is as good as the intermittent application of greater concentrations. Under some methods of treatment as much as 1 part in 5,000 parts of air is commonly used.

In the so-called trickle method of continuous application, now generally used in Florida, 1 to 2 cubic feet of ethylene per carload per day is sufficient. The temperature is raised by means of live steam and radiators; steam jets may also be used to provide humidity in cold weather. In hot weather, a fine spray of cold water is sometimes used to raise the humidity and to lower the air temperature. For best results the temperature of the air should generally be 82° to 85° F. and the relative humidity 90 to 92 percent. When Satsuma oranges are colored, a temperature somewhat below 80° is preferred.

A powerful fan is needed in the air-conditioning chamber to circulate the air around the stacked fruit and then withdraw it through the slatted floor to the air-conditioning chamber, from which it is recirculated. The fan should have a two-speed motor so that after the fruit has been brought up to the desired temperature the fan can be operated at low speed. This is important, inasmuch as long exposure to rapid air circulation tends to wilt the fruit if the humidity is too low. Provision should also be made for the continuous introduction of fresh air into the room and for the removal of the products of respiration, chiefly carbon dioxide; both of these are important.

As the fruit comes from the grove in field boxes it is stacked 5 or 6 feet high in the coloring rooms. When the crop has only a small percentage of fruit that needs degreening, it is customary to sort this out as it passes over the dumping belt instead of degreening the entire lot.

The height of the stacks in the coloring rooms depends on the weight of the boxes and the height of the ceiling. The common practice in Florida is to stack four standard field boxes (fig. 3) or five of the smaller field boxes. There should be a distance of at least 2 feet, preferably 3 feet, between the top box and the ceiling, to allow the good air circulation necessary to produce temperatures as nearly uniform as possible in all parts of the stacked fruit. If the air space is much more than 3 feet or less than 2 feet the rooms generally prove unsatisfactory and eventually have to be rebuilt.

Ordinarily it is neither necessary nor desirable to leave fruit in the coloring room until all of the green has disappeared. In mild weather fruit will continue to degreen for a short period after removal from the coloring room approximately as rapidly as that in the room. Oranges that are to receive the color-added treatment are not degreened as completely as those that are not to be dyed.

The time required for degreening depends largely on the variety and quality of the fruit, its stage of maturity, the coloring-room equipment (including insulation), and the weather. In general at the beginning of the season oranges that are green or nearly green require 48 to 60 hours to color. Later they may not require more than 24 to 36 hours, but regreened Valencias always take longer. About 12 hours less is required for grapefruit than for oranges. After the fruit has been degreened it should be packed and cooled as soon as possible.

Successful degreening requires alert and intelligent supervision, since it is the most delicate and involved part of the entire packing-

house procedure. In large houses it is common to have one man who thoroughly understands the process take complete charge of the coloring rooms.

The most common causes of failure or of difficulty in degreening are the following conditions in the grove or in the coloring rooms.

Conditions in the grove.—Oil sprays applied in late summer or too near the date of harvest are likely to retard degreening to a greater or less extent depending on the grade or type of oil, its concentration, and the number of applications. Under certain conditions, however, application of an oil spray after there has been a definite "color break" in the fruit does not retard degreening either on the tree or in the coloring room. Vigorous vegetative growth in very rich soils or excessive

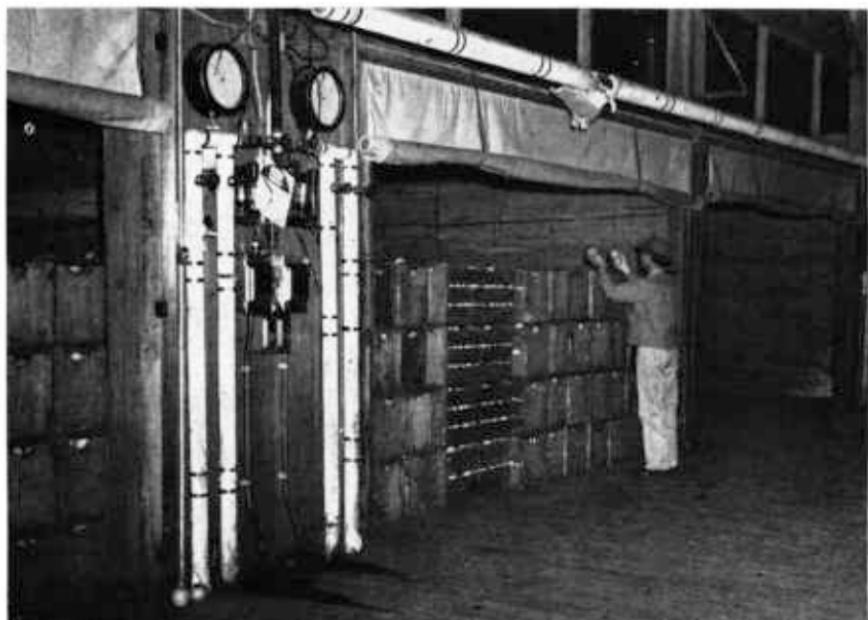


Figure 3.—Oranges in coloring rooms, receiving the ethylene treatment. The drop-curtain front across the end of the coloring room makes for easier hand trucking to the dumping belt.

applications of nitrogenous fertilizers produce fruit that is hard to degreen.

Conditions in the coloring rooms.—If the top fruit colors at a rate different from that of the bottom fruit, heating facilities are inadequate or there is insufficient air circulation to maintain a uniform temperature. In cool or cold weather slow coloring indicates inadequate heating facilities or insufficient insulation; in warm weather it indicates insufficient ventilation.

Noticeable wilting during the coloring process indicates too low humidity, excessive temperature, or more probably excessive air circulation even when the humidity is moderately high. Increasing the rate of air circulation calls for higher humidity in order to prevent wilting. A high rate of decay after degreening may be the result of insufficient ventilation and air circulation, of too much humidity if

the fruit has not been previously treated with an antiseptic, of using too much gas, or of exposing the fruit to the gas too long. Ethylene treatment stimulates stem-end rot; fruit known to be susceptible to stem-end rot should be gassed for not more than 64 hours.

SORTING OUT FROZEN AND GRANULATED FRUIT

When fruit is injured by freezing before it is harvested, there is a partial to complete loss of juice from the affected part, the extent depending on the length of time since freezing occurred. A symptom that can be readily detected immediately after the freeze is the presence of ruptured juice sacs. These may be confined to one or more segments or the entire fruit may be involved. This is followed in a short time by a buckling of the segment walls, especially at the stem end. Later the injured sacs collapse and dry out, starting usually at the stem end.

Another symptom of freezing injury is the presence of small, whitish, flaky spots (hesperidin crystals) in the segment walls of oranges and tangerines. These are easily seen almost immediately after a freeze; but as they are also produced by other causes they cannot be regarded as an infallible symptom of freezing injury. The presence of these crystals does not necessarily mean that the fruit will dry out and become worthless if left on the tree, but usually it may be taken as strong evidence that a damaging frost has occurred.

Outwardly frost damage is not likely to be manifested until the affected fruit has partly dried out. After this occurs, the rind over the affected area may be somewhat flat. It also becomes thickened.

Since frozen fruit usually shows no change of outward appearance or other symptoms of damage, it cannot be readily detected by the graders. Separation of frost-damaged fruit is usually done by the use of a specially constructed flotation tank. In this tank adjustable screens and flowing water separate the salable fruit from that which has lost too much juice. This method depends on the difference in the weight of the damaged and undamaged fruit. It is not altogether satisfactory even after considerable changes in weight of the fruit have taken place, but it is the best inexpensive method that has thus far been devised. Usually 2 or 3 weeks or even a month or more must elapse after the freeze before this flotation method can be used with any degree of dependability.

Borax antiseptic solution can be employed instead of water in the separation tank; then one operation does two jobs. When separating tanks of this kind are not used, workmen are stationed beside the soaking tanks to detect dried-out fruits by the manner in which they float. Those which float high in the water or on their sides are removed with long-handled kitchen strainers.

A specially constructed fluoroscope has recently been developed for detecting frozen fruit. In this machine the fruits are passed in single file through a specially illuminated chamber. The apparatus has a manually operated ejector to kick out any fruits the inspector considers damaged. This method is highly satisfactory, but expensive.

Regardless of the method employed, frozen fruit should be removed after it reaches the packing house and before it is washed.

Another type of drying out, called granulation, occurs commonly in oranges and to a limited extent in grapefruit. It shows up first in

large fruits, but eventually it appears in the smaller ones as well. It is characterized by the juice sacs being filled with solidified pectinaceous matter not readily soluble in water. In some fruits these solidified sacs seem to be distended.

Granulation usually sets in first at the stem end and may involve one-fourth or more of a fruit. In some of the early-ripening varieties conditions which favor rapid tree growth tend to produce large fruits that are susceptible to granulation before they become fully ripe. In the late-ripening varieties granulation does not usually appear until spring. Granulated fruits usually are lighter than normal; like frost-injured fruits, they can be detected in the soaking tank because they float high. There is no relation between the granulation and frost injury.

HANDLING MACHINERY AND PROCESSES

Hand trucks are used to move the fruit from the coloring rooms to the dumping belt or, if no degreening is necessary, from the receiving platform. This is the beginning of the mechanical system used to carry the fruit through the processing machinery to the packers. Each packing unit consists largely of a series of conveyor belts with accessories (fig. 4). It takes 10 to 15 minutes for a fruit to pass through the entire system, depending on the speed and size of the units. In some packing houses the machinery can be run at three speeds, the intermediate speed being the normal one. Sometimes a slower pace is necessary in order to dry or grade the fruit effectively; at other times the condition of the fruit makes greater speed permissible. The belts are generally made of thick-corded cotton, but wood rollers are also used.

A roller-type grading belt is used to rotate the fruit so it can be examined by the graders. Fabric belts are used when the fruit travels on a level, but on inclines roller or slatted conveyors are used.

Dumping Belt

To eliminate leaves, small twigs, and other litter that might be carried into the soaking tank, the dumping belt may be entirely of the roller type, or the fore part may be of ordinary cored belting with a section of roller conveyor just ahead of the soaking tank.

The dumper's job is one of the most laborious in the packing house (fig. 5). He must lift the heavy field boxes to the edge of the dumping belt and should carefully pour fruit out upon the moving belt. He must adjust the speed of his work to that of the machinery, because dumping too fast will bruise or crush the fruit or cause it to clog the machinery or to pile up somewhere and be damaged by the machinery; on the other hand, too slow dumping slows down all other operations and reduces the output. Dumping 3 or 4 boxes a minute is the average rate for an ordinary unit. At this rate the dumper has to lift and handle 60 to 70 tons of fruit per 8-hour day. Although a faster rate can be maintained where the equipment is of sufficient capacity, 1 man can seldom dump more than 9 boxes a minute. Some units can be operated at a rate of 12 boxes per minute when there are 2 dumpers. Sometimes each dumps for alternate periods of 10 to 15 minutes; or the 2 may work together to dump each box. As the fruit is dumped, the empty boxes are stacked 5 high on their sides to be trucked away.

In the larger and more completely equipped houses the empty boxes are placed on an overhead belt above the dumping belt, which conveys the crates outside the house, where they are stacked to await further use.

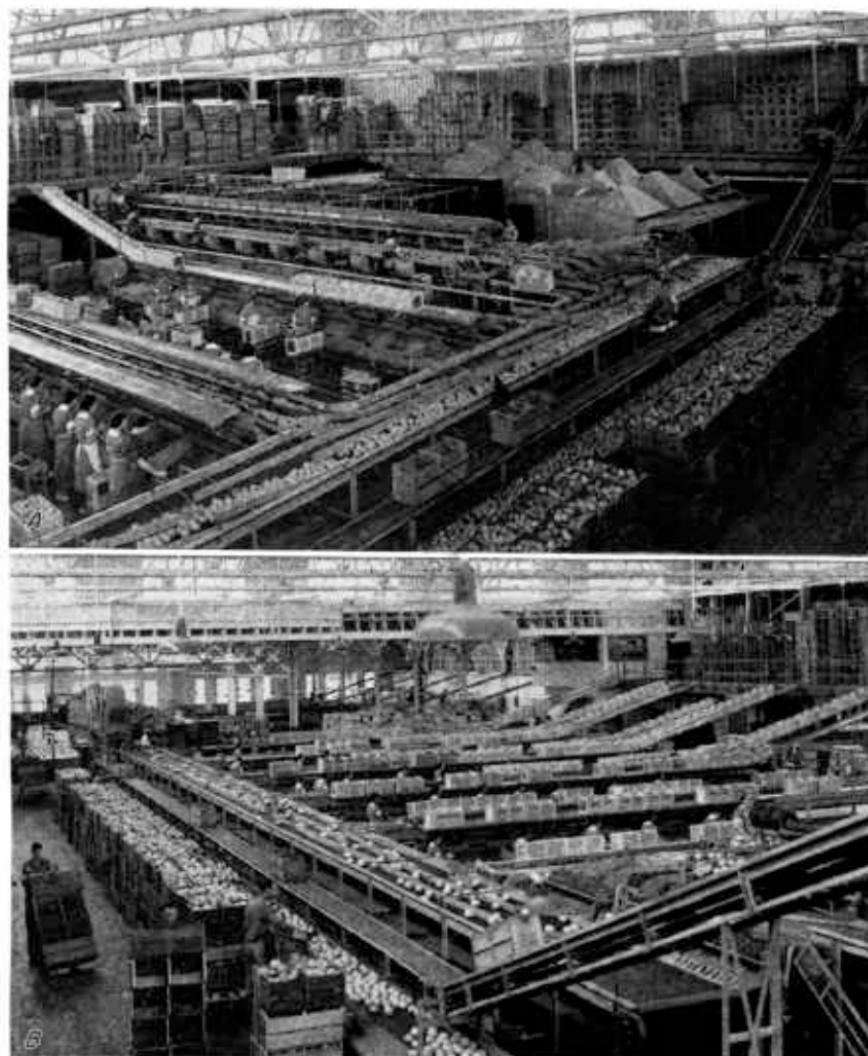


Figure 4.—A and B, Scenes in a well-equipped packing house, taken from the top of the range of coloring rooms. Note to the right in A the driers, polishers, and grading belt and on deck in background shook material. Note in B the hand truck, dumping belt, empty-box conveyor, stamping machine, and packers; precooling rooms are in the center background.

It is a good practice to have a man at the end of the dumping belt to sort out crushed or decayed fruit. This prevents unnecessary fouling of the soak tank into which the fruit is conveyed first and helps to keep the machinery clean. Fruit that is too green and there-

fore requires further treatment with ethylene can also be sorted out at this point.

There is sometimes a tendency to speed up the movement of fruit by loading the machinery beyond its normal capacity or running it excessively fast to economize on labor costs. However, this usually results in increased injury to the fruit out of all proportion to the increased output of packed fruit. It may produce a good showing on operation costs, but a bad decay record is almost sure to follow. Decay

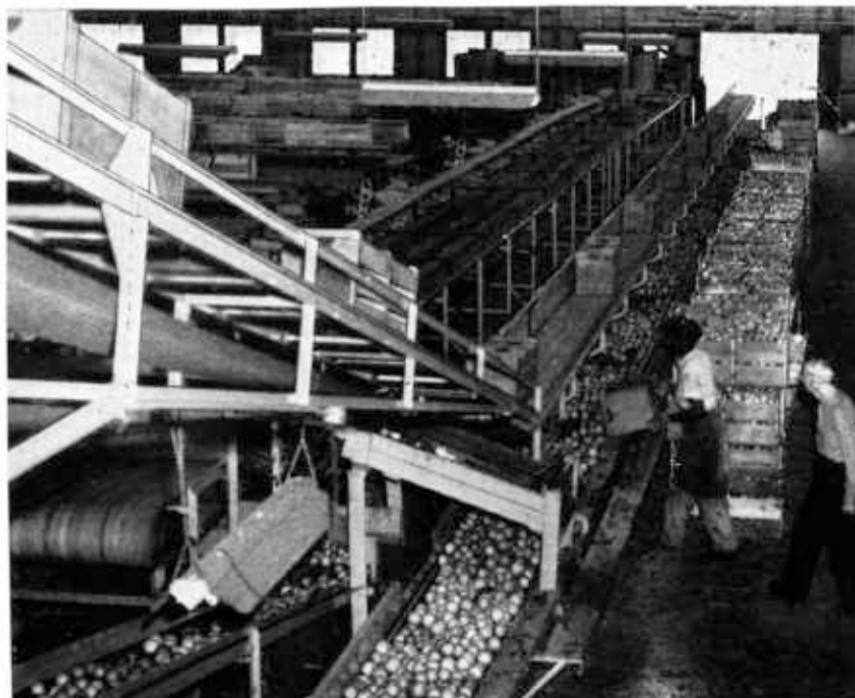


Figure 5.—Dumping oranges from field boxes. This is hard work which must be done with care to avoid crushing fruit as it rolls under the edge of the box. Note that two dumpers are working, one at each end of the row of filled boxes.

is often overlooked because it does not appear immediately and therefore is less tangible than the packing record.

Presizing

The fruit is often presized. Usually the presizer is located near the end of the dumping belt and ahead of the soaking tank; but in some packing houses presizing is done after the fruit is washed and waxed, before it reaches the grader. The sizing rollers can be set to throw out large or small fruit or both. The eliminated fruit is carried on conveyors to the cannery-stock bins. This procedure lessens the load on most of the machinery and reduces the amount of fruit that has to be handled by the graders; thus it may reduce the number of graders that have to be employed.

Washing

The fruit generally moves from the dumping belt to the soaking tank, usually located between the dumping belt and the scrubbing brushes (fig. 6). In some packing houses, however, fruit moves directly from the dumping belt to the scrubbing brushes. The soaking tank may be filled with unheated water to which some detergent is added. The cleaning process can be improved by heating the water in the soaking tank to about 100° F. by using live steam or steam coils placed in the bottom of the tank.

The detergents most commonly used are cheap soap powders, trisodium phosphate, soda ash, and other alkali or caustic-base materials, which sometimes contain soaplike rosin compounds with an

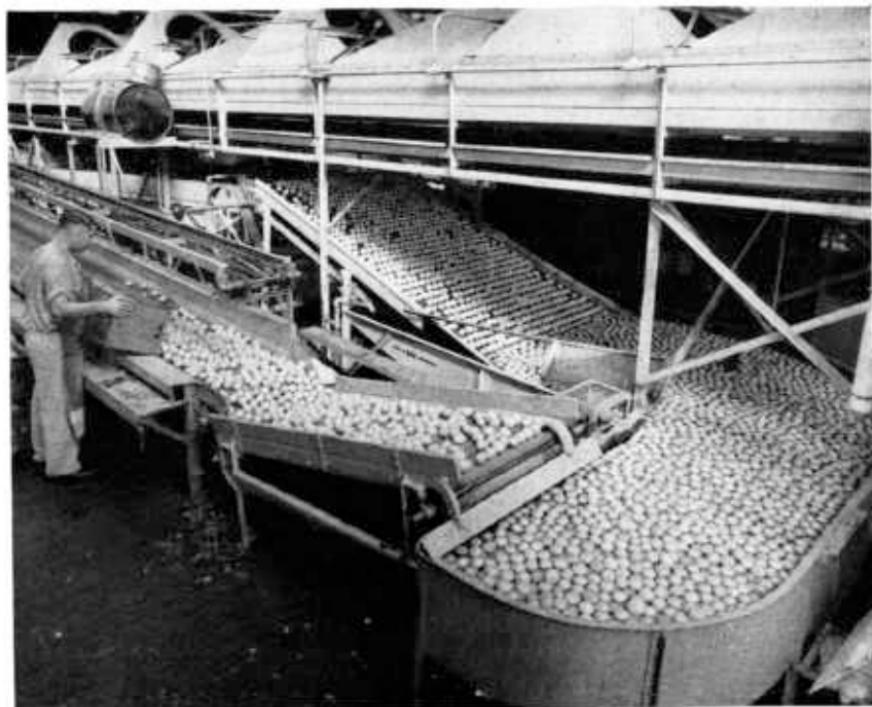


Figure 6.—The soaking, or flotation, tank. Here fruit on its way to the packers is washed and frosted or granulated fruit is culled.

agreeable odor. They loosen the dirt, spray residue, and other extraneous matter which may be on the surface of the fruit. Although these materials are excellent water softeners and satisfactory cleaners, they cannot be relied on to reduce decay, as often claimed. Besides being an aid in cleaning, heating the tank water warms the fruit and thus makes it easier to dry it when it eventually reaches the drier. Some packing houses have dispensed with soaking tanks except in handling frost-damaged fruit or that in which there has been marked drying out of the juice sacs due to granulation. In either of these cases the affected fruits float higher in the water than sound fruits and so can be easily detected.

The fruit is forced along through the soaking tank by crowding it full against a slatted wooden belt or escalator on the delivery end. This moves upward at an angle from beneath the surface of the water and carries the fruit to the top of the next machine, which is the washer.

A drag screen extending across the soaking tank removes sunken fruit, which otherwise would soon be injured if the tank water is heated. The proportion of sinkers varies not only as the season advances and the fruit becomes riper but also from crop to crop according to quality; the higher the quality the greater the proportion of sinkers, the maximum usually being reached in midseason for the variety, when the fruit is fully ripe.

Another way of meeting the sinker problem is through the use of a slatted false floor in the soaking tank, sloping toward the escalator.



Figure 7.—The ruffleboard washer, which has long been in use and thoroughly cleans round oranges, is considered easy on the fruit during the scrubbing operations.

Still another method is to use centrifugal pumps to circulate the solution in the soaking tank and drive the liquid with considerable force toward the escalator.

The ruffleboard washer (fig. 7) has several rows of circular roller brushes, usually more than 10 feet long, arranged parallel and lengthwise in the direction the fruit is traveling. This type of machine has many advantages, but it is being supplanted by a more efficient partially housed-in washer equipped with a series of about 30 transverse brushes. This washer is especially adapted to flat or oblong fruits such as tangerines and Valencia oranges. In it fruits are moved forward by one nudging another along as the escalator delivers the fruit wave by wave to the brushes (fig. 8). The brushes, made of

Tampico or palmetto fiber or other fairly stiff material, revolve at a high speed.

In some packing houses a suds-making apparatus (fig. 8) is placed above the scrubbing brushes to lather the fruit as it passes over the brushes. For this purpose a rather high-grade flake soap is dissolved and placed in the sudser along with a soap aid, soda ash, or other water softener when the wash water is hard; the object is to keep a thick lather of soapsuds on the fruit until it reaches the rinser near the farther end of the scrubbing brushes.

In other packing houses the detergent solution from the soaking tank is continually played upon the fruit as it passes over the scrubbing brushes. Whatever the method of scrubbing, the fruit is finally rinsed under jets of clean water as it leaves the washer.



Figure 8.—Transverse washer housed in to prevent the spattering of wash water. A catch basin located under the washer drains the water to the sewer. Transverse washers are better than ruffleboard washers for cleaning flat and oblong fruit. The suds-making machine functions by pumping compressed air into the shallow tank containing a soap solution. The overflowing suds fall on the fruit as it reaches the scrubbing brushes.

When soaking tanks are not used and fresh water only is sprayed on the scrubbing brushes, the cleaning is less thorough. Dry cleaning, or brushing the fruit without wetting it, is not generally satisfactory unless there is only dust to be removed. Ordinarily, however, other deposits such as the remains of scale and other insects and sooty mold fungus are encountered and can be removed only with difficulty even with the best washing equipment. When used, a dry-cleaning machine serves as a combination cleaner and polisher; but its disadvantages and limitations far outweigh any advantage for large operations, except possibly with tangerines and Satsuma.

oranges. However, for the small operator, such as one in the express-order business, a simple dry cleaner often suffices.

Color-Added Treatment

Next in the line after the washer is the color-added applicator if coloring is desired. There is usually a bypassing conveyor to shunt the fruit around the applicator when color-added treatment is not wanted. Oranges with the desired color at time of harvest, as well as tangerines and grapefruit, are bypassed around the immersion tank; or the flow of dye may be cut off as the fruit passes.

There is considerable variation in the color of oranges from time to time. This may be due to varietal differences or to differences in the same variety resulting from various factors. Several varieties of oranges reach maturity and are harvested at about the same season. Some of these ripen with a deeper orange color than others. Fruit from shaded, inside parts of the tree is likely to have a paler orange color than that from branches exposed to sunlight. The exposed cheek of outside fruit produced on the south and southwest sides of trees of deeply colored varieties is likely to become somewhat blanched by late winter and to have a decidedly paler color than the opposite cheek of the same fruit. This is especially true of Pineapple and Temple oranges.

Lack of uniformity of color may result in market discounts to the grower. Some markets prefer fruit with a deep color, and all want uniformity of color. In order to meet these market preferences, practically all packing houses in Florida and many in Texas are now equipped so that oranges may be treated with a certified food dye, such as is used in butter and candy. This treatment causes the rind of pale fruit to take on a deeper color and the two-toned fruit to assume a uniform color. The treatment is given between the washer and the polisher and is termed "color added" treatment to differentiate it from the gassing (coloring, or degreening, p. 9) treatment, which merely removes the green pigments from the rind.

In this process the fruit is subjected for 2 or 3 minutes to the dye solution, which is usually maintained at 120° to 125° F. by means of a thermostat. To avoid injury to the fruit the temperature of the bath should not be permitted to go above 127°, and the exposure at this temperature should not last more than 3 minutes. Unless this precaution is observed, collapse of oil cells and splitting of weak fruit may be expected. The depth of color attained is influenced by the temperature of the dye solution and the length of time the fruit is exposed to it; the higher the temperature or the longer the exposure the deeper the color.

In order to meet legal requirements, the juice quality as well as its quantity in treated fruit must be above that required for natural-color fruit. The degree of allowable color enhancement is also regulated by State laws enforced by inspectors supplied with color charts to serve as standards. Fruits colored in this way must be individually stamped "color added."

The color-added treatment can be given in an immersion tank filled with a dye solution, or the dye can be flooded on the fruit as it passes on a roller conveyor through a housed-in chamber with a tank underneath to catch the runoff. The immersion tank usually has steam

coils for heating the solution and a pump to circulate it. The flood-type color-added applicator is often equipped so that an antiseptic can be applied at the same time as the dye.

Next the fruit is passed over a few transverse brass rollers (fig. 9) to remove excess moisture before the fruit enters an antiseptic tank or the drier if an antiseptic is not used.

Antiseptic Treatment

The most convenient time to apply an antiseptic is just before the fruit enters the drier. Some packing houses pass the fruit through a tank containing a borax solution; others combine an antiseptic with the wax emulsion.

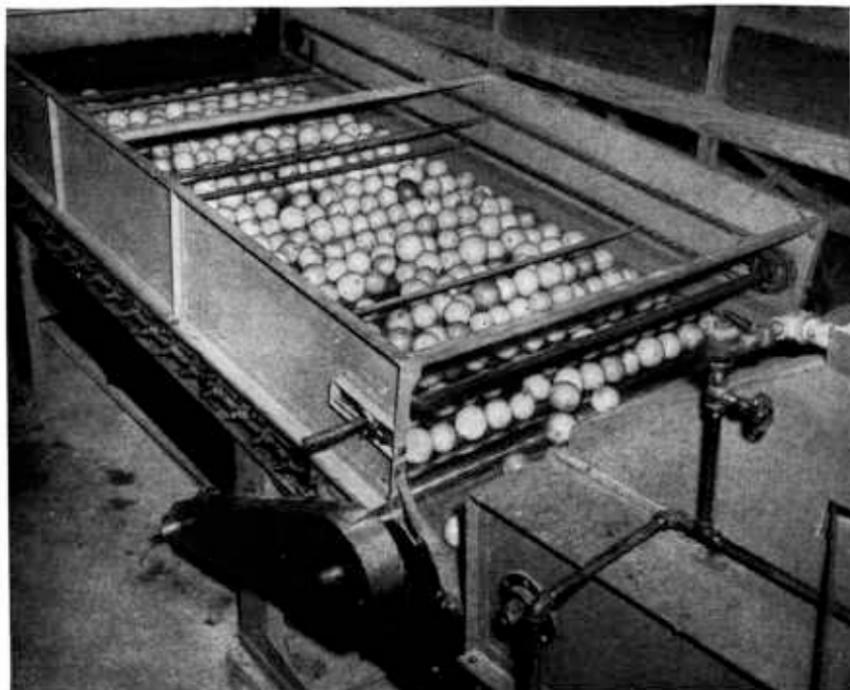


Figure 9.—Passing fruit over transverse brass rollers to eliminate as much of the adhering water as possible before the fruit enters the drier.

The design of the tank varies somewhat depending upon the type of antiseptic used. If a slow-acting antiseptic such as borax is used, the tank is oblong, several times as long as wide; if a quicker acting one is used, a small dipping tank (fig. 10) or a flood applicator suffices. (See fig. 36, p. 66.) The flood applicator is more satisfactory for wax emulsions and is an efficient means of applying certain antiseptics.

The antiseptic material most generally used is a 5- to 8-percent borax solution. In the treating tank the solution is heated by steam coils under thermostatic control to a temperature of 100° to 110° F. The treating tank is of sufficient size to retain the fruit 3 to 5 minutes. A final water spray is used to remove excess borax or other antiseptics.

material that adheres to the fruit after it emerges, and then the fruit is conveyed to the drier. Borax applied at this point is not so effective as if applied immediately after harvesting or upon receipt of fruit at the packing house. Such applications involve extra handling and therefore are not generally favored.

Sodium ortho-phenylphenate is sometimes used instead of borax. It can be applied in a small dipping tank, and the fruit is rinsed to remove the excess solution; or it can be combined with a wax emulsion (p. 21). If it is applied in combination with a wax emulsion, rinsing is omitted. Dipping the fruit in wax containing an antiseptic (fig. 10) has been replaced for the most part by the flood-spray method (see fig. 36, p. 66), which has proved more generally satisfactory. The tank is charged several times daily (p. 65) to replace the wax and

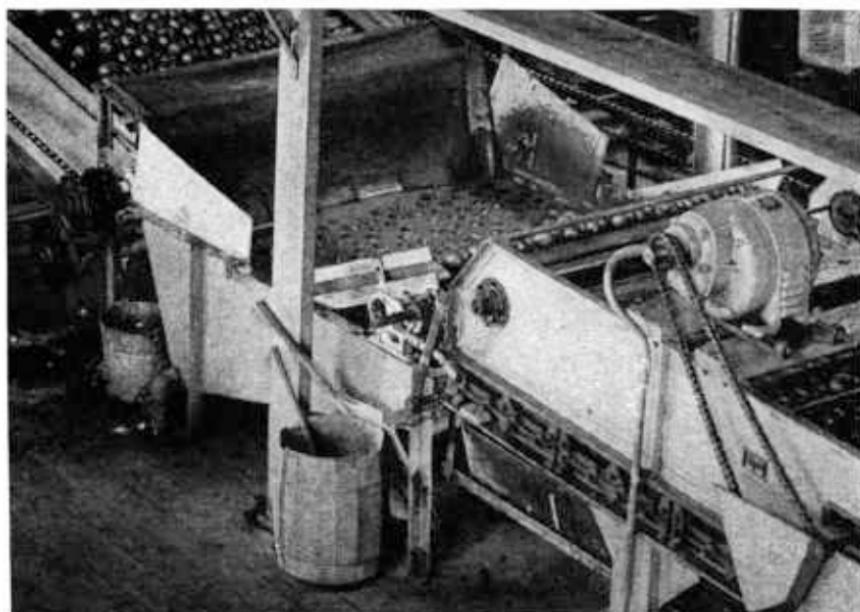


Figure 10.—A dipping tank for applying wax emulsion or antiseptic. Such a tank is not entirely satisfactory as a wax applicator, but it is a satisfactory means of applying a quick-acting antiseptic.

antiseptic removed by the fruit passing under the spray. Sodium ortho-phenylphenate is almost as effective as borax at its best for about 2 weeks, but it is more likely to cause rind injury. The concentration and the temperature must be constantly and carefully watched. When the fruit is heated as in the color-added treatment, it should not be subjected to more than a 1-percent concentration of sodium ortho-phenylphenate.

An entirely different method of suppressing decay is through the use of diphenyl in the container at time of packing. This method, which is described later (p. 66), differs from the ordinary antiseptic treatments in that the chemical is usually applied to the wrapping tissue or to a kraft-paper liner designed for the package instead of directly to the fruit.

Drying

The older type of drier, of which many are still in use, consists of a series of roller or slat conveyors enclosed in a sheet-metal housing equipped with a bank of steam pipes to heat the air that is blown on the fruit by powerful fans (see background, fig. 4, A). Using heated air increases evaporation from fruit that is not heated in the soaking tank or color-added applicator and during periods of high humidity. The conveyor system within the drier is so arranged as to provide two trips from one end to the other and back again; this ordinarily gives ample time for complete drying.

In recent years a more compact drier, built somewhat on the plan of the transverse scrubbing brushes, has come into use (fig. 11). It consists of a series of 40 to 60 roller horsehair brushes which are ar-

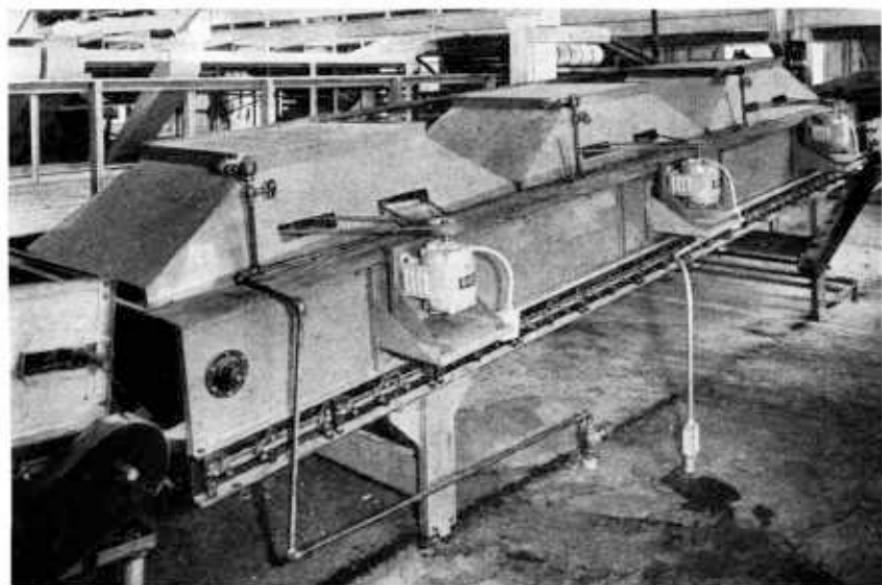


Figure 11.—A transverse-brush drier equipped with aero-fin radiators and fans for forcing hot air down on the fruit as it passes over the drying brushes.

ranged transversely to the flow of fruit and revolve at high speed. Above the brushes are located finned radiators and a series of fans to blow a blast of hot air onto the fruit as it passes beneath. This is a very efficient drier that can be located, if desired, above the washer or color-added equipment or alongside it, with saving of floor space. However, fruit dried in this manner is subjected to rather severe and undesirable pummeling. It has been shown repeatedly that unnecessarily prolonged brushing causes a break-down of the rind, which often is as serious as decay so far as market value is concerned. For this reason the older, less rigorous method of drying is preferable, but the new method, because it is so compact, seems to be displacing the older type of roller-conveyor drier.

The thorough drying of fruit is a matter of considerable importance. Damp fruit does not polish well, and dampness after packing increases susceptibility to decay.

Polishing

After the fruit is dried, it passes to the polisher. Two types of polishing machines are in general use. Sometimes both are used on the same unit. The newer type (fig. 12) is similar to the transverse-



Figure 12.—An efficient transverse polisher with horsehair spiral brushes. Unnecessary brushing by washer or polisher predisposes fruit to rind break-down.

brush drier but with the radiators and fans omitted. The other is a ruffleboard polisher, similar in design to the ruffleboard washer. It has several rows of horsehair brushes perpendicular to the direction in which the fruit is traveling and sloping downward. To retard the fruit and hold it against the brushes, ruffled canvas flaps about 4 inches

wide are attached at one edge to wooden boards parallel with the brushes. The fruit passes between the flap and the brushes. The ruffle-boards are suspended from metal rocker arms, and by means of eccentric gearing maintain a backward and forward motion of several inches. Either type of polisher or the combination of them ranges from 9 to 36 feet in length.

The transverse brushes have a greater capacity, but under certain conditions the ruffleboard polishers impart a higher polish to the fruit.

At some point along the line a polishing-wax material may be applied to the fruit. This is done to improve its luster and to retard the rate of wilting. When water-wax emulsions are used they are applied ordinarily before the fruit enters the drier, but sometimes while the fruit is on the brushes or immediately after it leaves them. The old

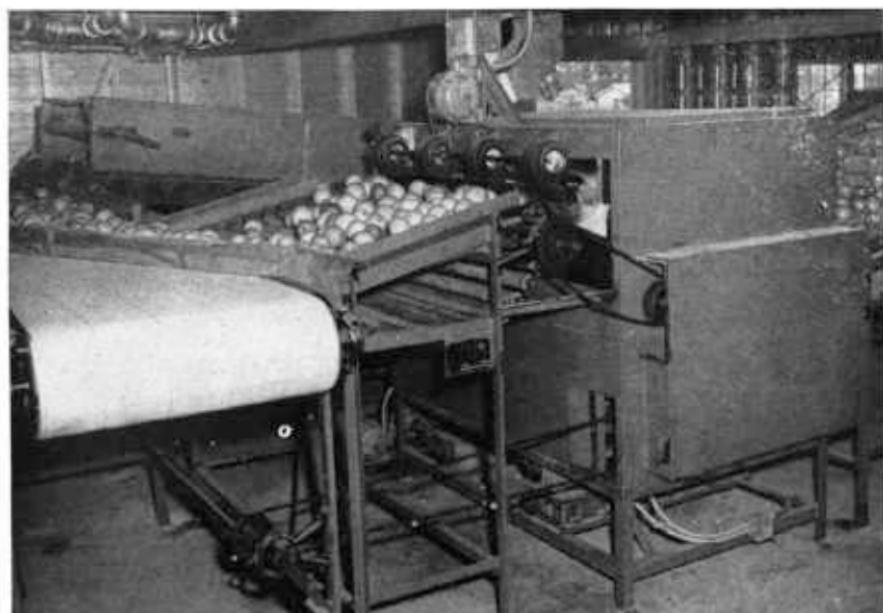


Figure 13.—A wax sprayer applying wax dissolved in a volatile liquid. Note the flue (upper center) for carrying the combustible fumes out of the building.

bar paraffin and brush method of waxing has been almost entirely displaced by more efficient materials and methods.

Another method is to use a mixture of melted paraffin and carnauba wax, which is usually applied as a spray when the fruit enters a covered and heated polisher. When the polisher is heated, a heavier application of wax usually results. The wax may also be dissolved in a volatile substance (naphtha or gasoline) and lightly sprayed on the fruit as it leaves the polisher. This process is in rather general use (fig. 13) and results in a satisfactory luster but is less effective in retarding wilting.

By still another method the wax mixtures are emulsified, diluted with water, and showered on the fruit before it enters the drier (see fig. 36); or the emulsion is placed in a small soaking tank located immediately

before the drier (fig. 10). Because of the tendency of the emulsion to break down from the action of fruit acid, the dipping-tank method of applying wax is not entirely satisfactory. It is, however, a good but not necessarily better method of applying certain antiseptics such as the soluble phenates when they are combined with the wax. In some houses a wax-emulsion-phenate mixture is applied as an undercoat, with another application of wax following after the fruit has dried.

Carnauba wax produces a high luster but is not so effective as paraffin in retarding wilting. Paraffin, on the other hand, does not develop a high or enduring luster. For these reasons mixtures of paraffin and carnauba wax and at times of other waxes or gums are generally used. These give a satisfactory luster and check wilting. If the object is mainly to have a high luster when the fruit reaches market, carnauba or carnauba-base waxes are chosen; if it is shrinkage control that is desired, waxes consisting mainly or solely of paraffin are used.

Discretion should be used in applying waxes. If the application is too light it may give a satisfactory luster but may not be sufficient to check wilting or keep the rind fresh and pliable. On the other hand, if the fruit is too heavily coated, the flavor may be impaired through interference with normal respiratory activities. Unwaxed fruit can be polished to a very good luster by brushing it well, because it is covered with natural wax. The natural fruit wax, however, is not effective in checking wilting.

Grading

After the fruit is cleaned and polished, it is sorted into several grades. The grading belt is a roller belt, usually about 2 feet wide, which continually turns the fruit so that it is not necessary for the graders to pick up each individual fruit to search for defects.

The graders at the head of the line are expected to pick out the cull fruit and lowest grade fruit, which includes that with the worst blemishes. Decayed and injured fruit is sent to the cull bin and ultimately is hauled away and dumped. The blemished but otherwise sound fruit is conveyed to large bins, from which it is shipped in bulk to canneries or sold to itinerant truckers.

Fruit of the higher grades is generally packed for shipment, but large quantities of first- and second-grade fruit, especially that of the very large and very small sizes, are also sold to canneries. This class of fruit usually sells at a discount.

The graders sort the fruit according to the requirements of each of the various established grades (p. 27), placing each on a separate belt. By means of shunts and chutes each of these finally conveys its fruit through the sizers to the packing bins, each of which receives a particular size of the grade.

Frequently the individual fruits are marked to indicate the locality where grown, the brand or grade, or any special treatment given. It is mandatory to stamp the words "color added" on each fruit so treated. This is done with a motor-driven stenciling machine located between the polisher and the grading belt or between the grading belt and the sizers. This machine is adjusted so as to mark each passing fruit regardless of its size.

Commercial citrus fruit is graded primarily on its surface appearance. Discoloration, scarring, texture of skin, and freedom from scale insects and surface growth of fungi or algae are the chief factors that are considered in grading. Grades and standards of the United States Department of Agriculture are usually applied.¹

The head grader, who is in immediate charge of the grading crew, has the responsibility for properly grading the fruit. In conjunction with the house foreman he usually makes a preliminary examination to determine the particular grades into which a given lot should be sorted. Ordinarily the fruit in a single run comes from the same grove and has the same general characteristics, so that it can be sorted into not more than 3 or 4 grades and usually into only 2 or 3. This important work is performed by 5 to 10 graders (fig. 14), who work along each unit of the grading belt.



Figure 14.—Grading fruit. From tree to market, hands touch fruit only three times: (1) In picking, (2) in removing low-grade fruit during grading, and (3) in packing.

Grading the fruit is the only manual operation between the dumper and the packer at the end of the processing line. Each sorter should wear gloves to prevent fingernail punctures to the rind, for they pave the way for decay.

Sizing

After the fruit has been sorted and graded, it passes through the stamping machine to the sizing belt and then drops into the packer's bins. Each sizing unit has eight or nine packer's bins, with canvas bottoms, arranged in rows at right angles to the grading belt. The sizing equipment in general use consists of revolving wooden or metal rollers set parallel to the conveyor belt and above it but gradually

¹The specifications for these grades can be obtained from the Fruit and Vegetable Branch, Production and Marketing Administration, U. S. Department of Agriculture, Washington 25, D. C.

verging away from it. The fruit is carried along on this moving belt, which is located at the upper edge of the bins and inclined toward them (fig. 15). Thus as individual fruits reach the roller for that size they pass under the roller into the bin. This makes it possible to obtain a uniform pack with fruits of approximately the same size. Citrus sizes are designated by the number of fruits that can be packed in the standard box. The sizes and the corresponding diameters of oranges, grapefruit, and tangerines are shown in table 2.

Formerly itinerant truckers bought much bulk citrus fruit on the basis of the minimum and maximum sizes used for boxed fruit; but



Figure 15.—A sizing machine, which causes individual fruits of the same approximate diameter to fall in the same bin. The smallest fruit is the first to fall and the largest the last. The fruit shown is being sized for specialty packages.

now most bulk fruit is sold to canneries, usually by weight and grade. (See table 5, p. 54.)

Packing

Despite all the handling to which citrus fruit is subjected the packing-house machinery is usually operated so carefully and competently that ordinarily there is little injury to oranges and grapefruit. The principal exception occurs when excessive brushing is done. This is especially bad for tangerines, which are also easily injured by the roller conveyors. For this reason some packers do not brush tangerines to polish them, but use a liquid polishing material that dries with a luster. Slat conveyors rather than roller conveyors should be used whenever possible.

Most packing-house employees are paid at an hourly rate; but packers are paid on a piecework basis, receiving a specified amount per packed container. The scale, based on the standard box, is about half

TABLE 2.—*Diameters of different-sized oranges, grapefruit, and tangerines in Florida boxes*

Kind of fruit and size	Minimum diameter	Maximum diameter
Oranges:		<i>Inches</i>
96's	$3\frac{6}{16}$	$3\frac{11}{16}$
126's	$3\frac{3}{16}$	$3\frac{8}{16}$
150's	3	$3\frac{4}{16}$
176's	$2\frac{14}{16}$	$3\frac{3}{16}$
200's	$2\frac{12}{16}$	3
216's	$2\frac{10}{16}$	$2\frac{14}{16}$
250's	$2\frac{8}{16}$	$2\frac{12}{16}$
288's	$2\frac{6}{16}$	$2\frac{10}{16}$
324's	$2\frac{4}{16}$	$2\frac{8}{16}$
Grapefruit:		<i>Inches</i>
36's	5	$5\frac{1}{16}$
46's	$4\frac{11}{16}$	$5\frac{2}{16}$
54's	$4\frac{6}{16}$	$4\frac{13}{16}$
64's	$4\frac{3}{16}$	$4\frac{9}{16}$
70's	$3\frac{15}{16}$	$4\frac{5}{16}$
80's	$3\frac{12}{16}$	$4\frac{2}{16}$
96's	$3\frac{9}{16}$	$3\frac{15}{16}$
126's	$3\frac{5}{16}$	$3\frac{11}{16}$
Tangerines:		
100's	$2\frac{15}{16}$	-----
120's	$2\frac{11}{16}$	-----
150's	$2\frac{8}{16}$	-----
176's	$2\frac{5}{16}$	-----
210's	$2\frac{2}{16}$	-----
246's	$2\frac{1}{16}$	-----
294's	2	-----

as much for grapefruit as for oranges. Tangerines are packed in half boxes; the rate is about the same as for full boxes of oranges.

Major importance is attached to the appearance of the package. In the larger packing houses a supervisor watches all packers closely in order to maintain a high standard.

The packing inspector or supervisor has the responsibility for proper sizing and packing. He also assigns the packers to various sizes in rotation so as to equalize the work and to give each one a chance to pack the larger sizes.

Most of the packing is done by women who have mastered the art after long practice. In a day a good packer can turn out 70 to 80 standard boxes of oranges, about the same number of the smaller packages of tangerines, or an average of about 150 boxes of grapefruit (fig. 16). A packer can put out in a day about twice as many wire-bound crates of nonwrapped fruit as standard crates of wrapped fruit. Wire-bound crates are being used more generally because the fruit is not wrapped and the packing cost is thus reduced.

Sometimes fruit packed in standard boxes is not wrapped. For oranges of size 250 and smaller, the so-called blind pack may also be used. In this pack only the fruits in the top and bottom layers and those that are visible through the open spaces in the box are wrapped. To save paper during World War II, only the top two layers were wrapped. Because of the added cost of packing wrapped fruit,

there was a general tendency to eliminate wrapping altogether.

To obtain a firm pack in standard boxes, the fruit is somewhat pyramided toward the center partition by pressing it down in the ends of the box and also by placing a little larger fruit against the center partition. Slight variations in size of fruit in the same bin make it possible to do this.

When the fruit is wrapped, the printing is arranged in an orderly manner and no "flags" (loose wrapping tissue) are permitted to show through the open spaces in the box. In packing houses catering to a discriminating trade the wrap is twisted tightly around each fruit, especially the fruit placed along the open spaces in the box and in the top layer. Twisting, however, slows down the rate of packing. In some packing houses only the fruit in the uppermost layer of the box



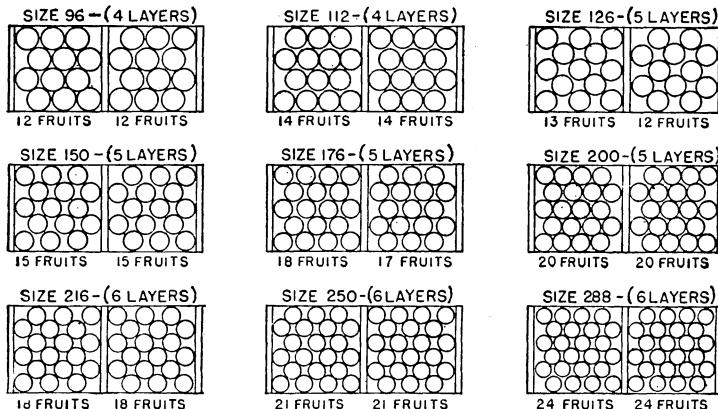
Figure 16.—Packing grapefruit in standard boxes. Note the bulge toward the center of the boxes and the cardboard collars, or "no-cut guards," at the tops of the boxes to prevent the upper layer of fruit from receiving box cuts.

is wrapped with the tightly twisted paper and the remainder is merely cushioned in wraps. This practice, known as wadding, is not generally favored, because it encourages carelessness.

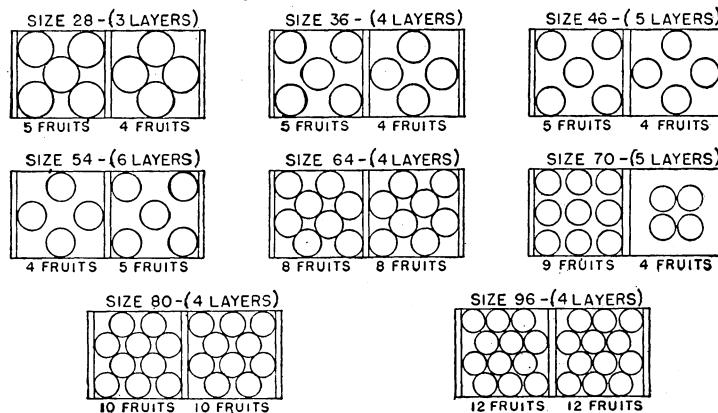
The packer places each individual fruit symmetrically in the container in such a manner as to provide a firm pack that will withstand jolts and jars without bruising or other damage. Figures 17 to 19 show how the various sizes are packed in the different layers of standard boxes and wire-bound crates.

If the fruit is wrapped, a lightly oiled tissue paper is ordinarily used. This is easier to work with and somewhat tougher than the common nonoiled, or dry, tissue paper. On an average about 40 reams of paper is required for each 100 boxes of oranges or tangerines and about 20 reams for the same number of boxes of grapefruit. The

ORANGES



GRAPEFRUIT



TANGERINES ($\frac{4}{5}$ -BUSHEL BOX)

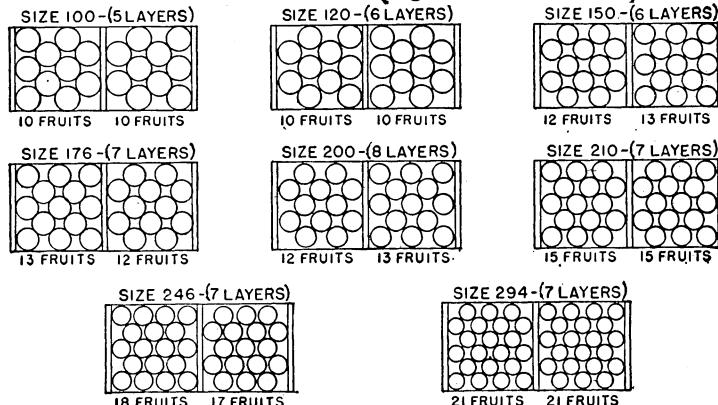
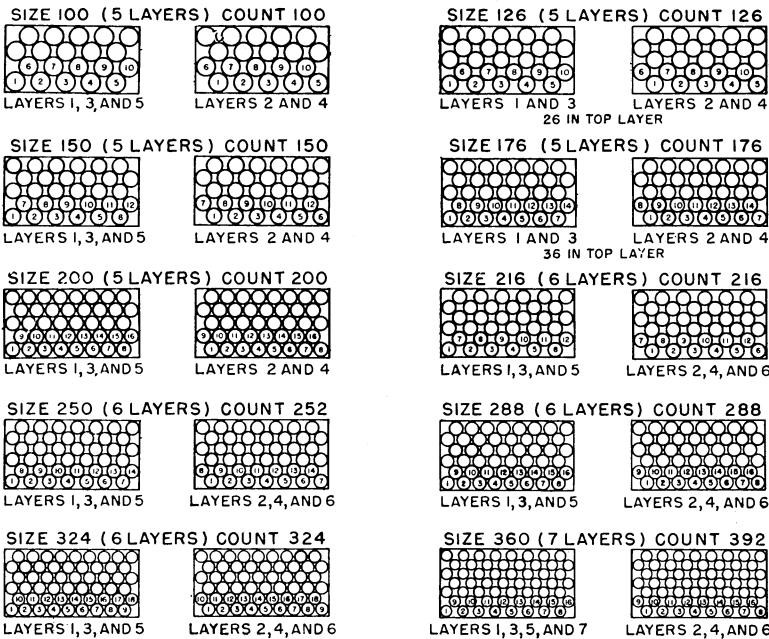


Figure 17.—Charts showing the various packs used for oranges, grapefruit, and tangerines in standard crates. The left half of each diagram shows the arrangement of the fruits in the first, or bottom, layer of the box and each alternate layer above it, and the right half shows the arrangement of fruits in the second layer from the bottom and each alternate layer above that.

ORANGES



GRAPEFRUIT

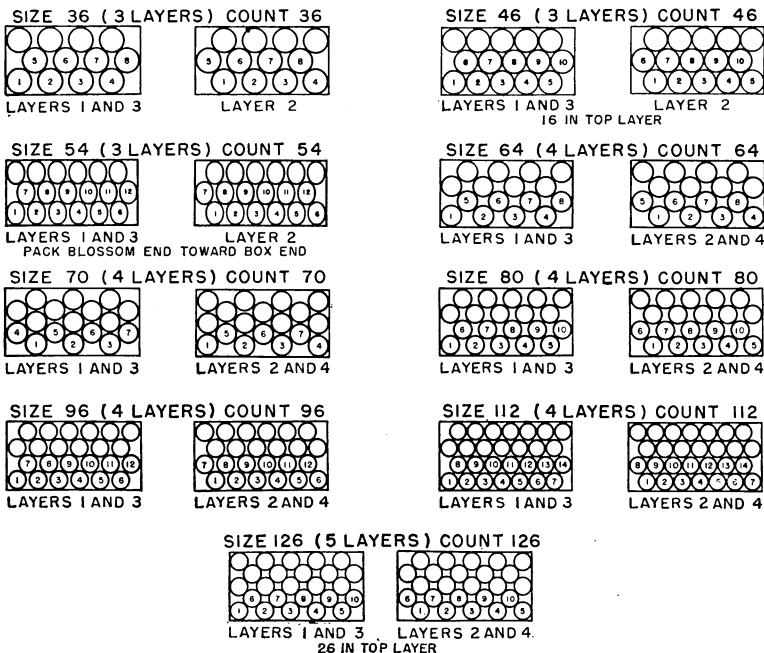


Figure 18.—Pack diagrams for standard (wire-bound) 1 3/5-bushel Bruce box for oranges and grapefruit. Numbers in circles indicate order of packing.

sizes of wrapping tissue used for fruit of various sizes are shown in table 3. Oiled paper treated with diphenyl is also being used to some extent. The diphenyl volatilizes slowly and the fumes protect the fruit from decay during the usual marketing period. Good decay control

TANGERINES

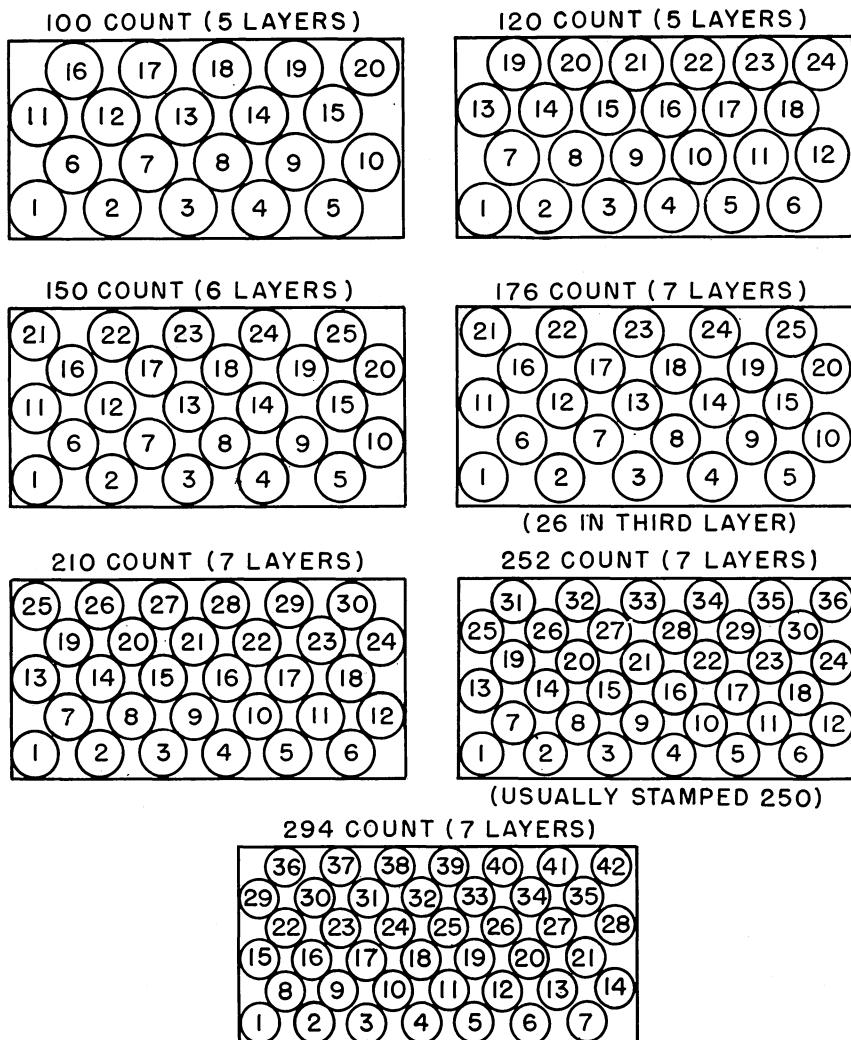


Figure 19.—Pack diagrams for $4\frac{1}{2}$ -bushel Bruce box for tangerines. Numbers in circles indicate order of packing.

can also be obtained by using diphenyl-treated pads between layers of fruit or by using crate liners similarly treated with diphenyl (p. 66). For a short time after unpacking, the odor and flavor of diphenyl can usually be detected in the rind, but not in the flesh or juice of the fruit.

In order to reduce the loss in weight through evaporation, moisture-proof wrappings such as pliofilm, cellophane, and aluminum foil are used to a limited extent. Packages containing fruit wrapped in these materials make a distinctive appearance, and usually the fruit remains fresh and turgid, with very little loss of weight during prolonged storage. However, surface mold and loss from decay may be increased because moisture transpired from the fruit cannot escape. These wraps and liners are considerably more expensive than ordinary sulfite tissue.

TABLE 3.—*Size of tissue wrappers for citrus fruits of various sizes in the Gulf Coast States*

Kind and size of fruit	Size of tissue wrap	Kind and size of fruit	Size of tissue wrap
Tangerines:		Grapefruit:	
250's and smaller-----	<i>Inches</i> 9 by 9	126's-----	13 by 13
216's, 196's-----	10 by 10	96's-----	14 by 14
168's, 144's-----	11 by 11	80's, 70's, 64's-----	15 by 15
120's and larger-----	12 by 12	54's, 46's-----	16 by 16
Oranges:		36's-----	17 by 17
250's and smaller-----	10 by 10		
216's, 200's-----	11 by 11		
176's and larger-----	12 by 12		

It is important for the packers to wear gloves to prevent fingernail puncturing of the fruit while they are wrapping it or placing it in the box. Injury of the fruit through careless packing operations can nullify all of the precautions taken previously to prevent decay.

After being packed, the boxes are placed on a conveyor belt which carries them to the nailer, who applies the tops. To make the package more secure, a metal strap is drawn tightly across the top over the center of the standard box and nailed to the center partition. This work is done with the aid of a lidding press (fig. 20). An elaborate hydraulic or mechanical lidding press which holds the box top so that it can be nailed in place is sometimes used. A mechanically operated combination top press and nailer is also used to some extent. As the boxes are lidded, the nailer stacks them on the floor, four high, on their sides; or he sends them along on the conveyor belt to a precooling room or to the loading platform.

After the boxes are lidded, care must be taken to prevent any undue pressure on the bulged top. The amount of the bulge varies; for oranges it is $1\frac{1}{4}$ to $2\frac{1}{4}$ inches and for grapefruit 2 to 3 inches, measured above the sides. If the bulge is less than that mentioned, a slack pack may result by the time the fruit reaches the market. If the bulge is as high as often demanded by buyers, especially in an excessively tight pack, there is often considerable damage because of heavy pressure. The danger of box cuts is also increased by high-bulge packs, but it can be averted to some extent by the use of cardboard collars around the tops of the boxes (fig. 16).

In order to protect the fruit in the bulge part of the box, a stick or rider equal in length to the width of the box is placed over the center

partition. A $1\frac{5}{8}$ -inch rider is used for oranges, a $2\frac{3}{8}$ -inch rider for grapefruit, and a $1\frac{1}{4}$ -inch rider for tangerines.

The lid of a wire-bound crate is closed with a special tool, usually while the crate is on the conveyor (fig. 21). Proper closure is very important to avoid breakage, especially when the boxes are somewhat overfilled. Overfilling containers of this type is especially serious because of the bruising and crushing likely to result when they are stacked.

Choice of Type of Container

Various containers are used. The one in use over the longest period is the standard, or two-compartment, nailed box constructed of pine or



Figure 20.—Lidding a standard box. Note the mechanized device for pressing the top down on the box and the wire strapping across the middle of the lid.

veneered gum (fig. 22, A) and with a capacity of 1.6 bushels. It is somewhat larger than the standard California box, which has a capacity of 1.47 bushels. The over-all length of the Florida standard box is 27 inches; and each compartment is 12 by 12 by 12 inches, inside dimensions. The California standard two-compartment orange box has an over-all length of 26 inches; and each compartment is $11\frac{1}{2}$ by $11\frac{1}{2}$ by 12 inches, inside dimensions. In Texas the Florida and California boxes are both used, but the former is in more general use because of its adaptability to grapefruit, which constitutes the bulk of the Texas citrus crop.

The nailed shallow half box ($\frac{4}{5}$ -bushel capacity) is not so generally used for oranges as formerly, but it is still widely used for Temple

and Satsuma oranges and to a less extent for tangerines. This container is commonly known as the "half strap," because of the method of shipping in which two boxes were strapped together at bottom and top—a method now discarded. These half boxes have two compartments and the same dimensions as the standard boxes except for the depth, which is 6 inches.



Figure 21.—Lidding a wire-bound crate with the aid of an instrument specially designed for the purpose. This operation is rapid. Fruit is not so likely to bruise in wire-bound crates as in standard ones.

Another $\frac{4}{5}$ -bushel nailed box, $9\frac{1}{2}$ by $9\frac{1}{2}$ by $19\frac{1}{8}$ inches, inside dimensions, patterned after the standard box, is most commonly used for tangerines, Temple oranges, and limes.

Within the past 15 years the single-compartment, wire-bound crate has gained greatly in popularity in the Gulf coast region and is now in more general use than the standard nailed box. It has the same capacity as the standard nailed box but is built of lighter material and is cheaper. Fruit packed in this container is rarely wrapped, so that

when such a container is used less labor is needed and packing operations can be speeded up. The $1\frac{3}{5}$ -bushel wire-bound crate is used for oranges and grapefruit; the $\frac{4}{5}$ -bushel crate patterned after the larger one is widely used for tangerines, Temple oranges, and limes.

Bushel potato crates and bushel as well as half-bushel baskets are also used, the first almost exclusively for tangerines and Temple oranges; baskets are commonly used for express shipments of citrus fruits in general.

Box shook, consisting of ends, center partitions, sides, and bottoms, is usually bought by the packing house; and the boxes are made up generally by automatic nailing machines, but sometimes in the smaller houses by hand. All wire-bound crates are received in bundles and are made up by hand at the packing house. A particular section of the house is devoted to this work. In Florida it is often a balcony over

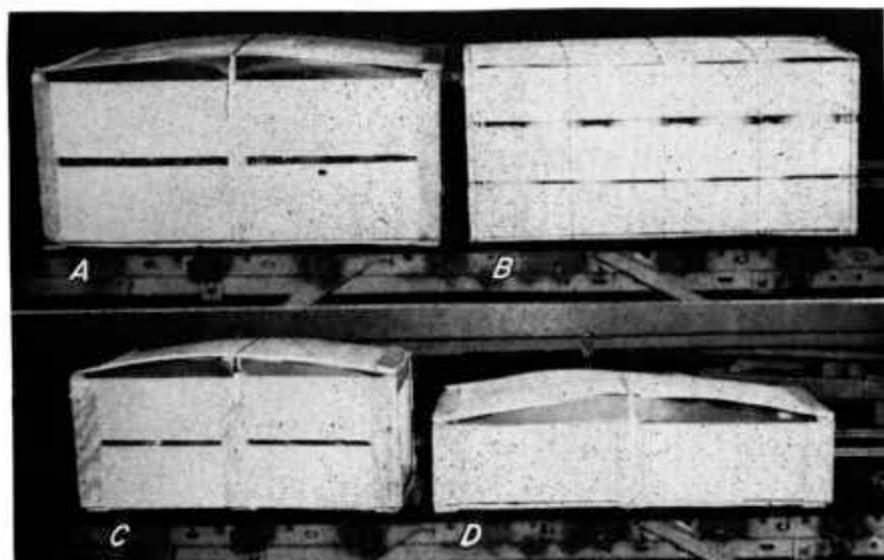


Figure 22.—Four of the types of containers used in Florida: *A*, $1\frac{3}{5}$ -bushel standard box; *B*, $1\frac{3}{5}$ -bushel wire-bound crate; *C*, $\frac{4}{5}$ -bushel standard box; *D*, $\frac{4}{5}$ -bushel "half strap" (half box).

the coloring or precooling rooms; in Texas it is usually the basement. After the containers are made up, they are labeled and stacked to await use. As needed, they are placed on runways above or below the packing bins so as to be easily available to the packers.

The open-mesh cotton or twisted-paper-fiber bag is coming into wide use as a container for both grapefruit and oranges, especially for distribution through chain stores. The half-box size (holding about 40 pounds) also is used for grapefruit. The most popular bag for oranges is the 8-pound size; and even the 5-pound size is gaining favor because it is a satisfactory consumer package for both oranges and grapefruit.

The earlier handicaps found in filling mesh bags with citrus fruit have now been met satisfactorily. The $\frac{4}{5}$ -bushel bag is attached to a circular holder hung at the side of the bin. This simple attachment

can easily be removed from the bin when not in use. Several machines have been designed for filling bags; some of these are counterpoised so that the flow of fruit is stopped when the desired weight of fruit has fallen into the bag. Such a machine enables an operator to fill and tie bags more rapidly than he can pack the same amount of fruit in wire-bound boxes. Since the machine is on casters, it can be moved about without difficulty; this enables the packing house to shift to or from packing mesh bags without delay. Stapling machines are also used to secure the drawstring; their use further increases the packer's daily output. Citrus fruit in mesh bags is hauled by hand trucks or by endless conveyors to the platform for loading into the refrigerator cars.



Figure 23.—Multiwalled paper bags, which make neat and satisfactory containers for citrus.

Recently $4\frac{1}{2}$ -bushel and also 8-pound multiwalled paper bags (fig. 23) have also come into use to a limited extent. The principal advantages of the paper bag are its economy and the speed with which it can be filled and closed either by wire tying or sewing. Another advantage of the multiwalled kraft-paper bag is that the inner wall can be treated with diphenyl to retard decay.

World War II conditions brought still another container into limited use—a fiberboard carton of 1-bushel capacity or slightly less. Several designs with or without separator trays between layers of fruit were offered. Those without separator trays proved satisfactory for tangerines and small oranges. Cartons with trays are considerably more expensive, and for that reason their use is likely to be limited to the highest quality fruit. These trays can be treated with diphenyl for decay control during the marketing period.

COLD STORAGE

It is generally considered that oranges, and especially grapefruit in the early stages of maturity, will keep better on the tree than if picked and placed in cold storage. However, conditions sometimes arise that make it necessary to store citrus fruit for various lengths of time. Glutted markets, embargoes, and rapid changes in the fruit itself, especially regreening, are the principal reasons for placing citrus fruit in cold storage.

Fruit that is well advanced in maturity at the time of picking is not suitable for long storage. In general, the less mature the fruit is when harvested the better it will keep in storage, particularly with respect to decay.

Oranges will ordinarily hold up well in cold storage at 34° F. for only 1 or 2 months, but fruit from some groves can be held for 3 or 4 months or even longer. The relative humidity of the cold-storage rooms is very important and should be maintained at 85 to 90 percent. Lower humidity tends to cause the fruit to shrivel and lose weight, and a slack pack results, whereas higher humidity favors the development of mold on the fruit and package and also causes the veneered panels of the crates to warp. If the storage period is not to exceed a month or 6 weeks 38° is about as satisfactory as a lower temperature and is customarily used in the markets. If the storage period is long and the room is maintained at 32°, a low-temperature rind break-down known as watery break-down, brown stain, and other physiological troubles are likely to result, but loss from decay will be less. In general, the longer oranges are held in cold storage or the higher the storage temperature, the more rapid will be the rate of spoilage after transfer to household temperatures.

Grapefruit cannot be stored satisfactorily at low temperatures for more than a short time, because pitting frequently develops and other troubles develop within 4 or 5 weeks. Some of the rind disorders may appear while the grapefruit is held at the low temperature, but others do not show up until the fruit is withdrawn to a warm temperature. Susceptibility to these troubles varies greatly. Fruit from one grove may become affected within 30 days, whereas that from another may remain entirely free from trouble or fail to develop any symptoms until weeks later. Although these troubles are only skin blemishes, they are unsightly and affect the market value of the fruit.

At temperatures around 50° F. pitting rarely develops to a serious extent on grapefruit, but fungus rots are favored. Consequently long storage at 50° is not generally satisfactory. However, proper use of antiseptics at the time of harvesting or packing reduces the danger of loss on this account. The use of diphenyl-treated wraps and case liners is also helpful in preventing decay during storage.

PRECOOLING

“Precooling” is the term commonly applied to the artificial cooling of fruit before shipment. It is done either in the car after loading or in specially constructed rooms in the packing house.

The most important benefit from precooling is checking the growth of decay organisms. Such rapidly growing organisms as those causing stem-end rot thrive best at high temperatures and are effectively re-

tarded when the fruit is promptly precooled. At low temperatures the spores of many other decay organisms will not germinate and infections already started develop but slowly, so that these rots are likewise retarded or prevented altogether as long as the fruit is held at a sufficiently low temperature. Low temperatures also preserve the appearance and fresh flavor of the fruit. The best equipped packing houses have precooling rooms in which the fruit is placed for precooling unless it is to be loaded and shipped within 24 hours after picking, especially during warm weather. These rooms are suitably

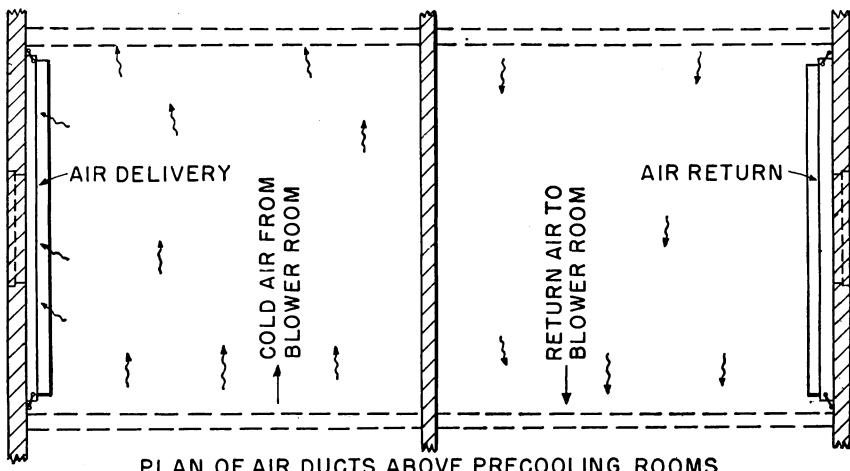
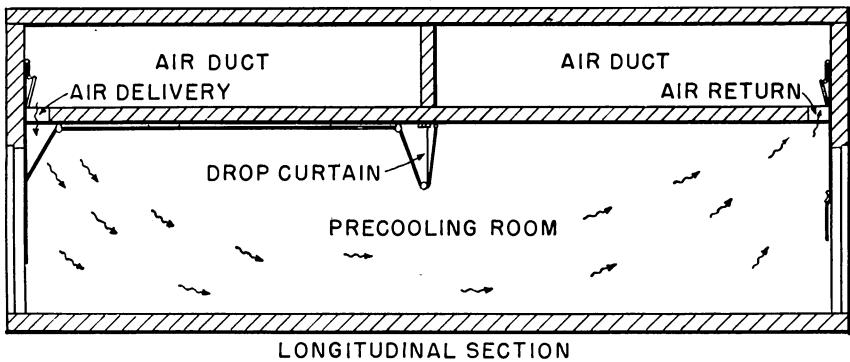


Figure 24.—Diagram showing air circulation in a typical precooling room.

insulated and are refrigerated by a forced draft of air from a bunker room.

In figure 24, a diagram of the air circulation in a typical precooling room with overhead air ducts connected to the blower room is shown. The cold air under pressure from the blower room is forced through one of the two air ducts and down into the precooling room below through an opening in the ceiling. It then goes through the stacks of fruit and up through the opening in the ceiling at the opposite side of the room into the air duct above for return to the blower room.

A canvas baffle extends across the center of the room and can be lowered by means of a rope from the ceiling to the top of the stacks. This is used to prevent short circuiting of the cold air over the top of the boxes and to force it through the stacked fruit (fig. 25). The direction of the air blast is reversed periodically to help equalize the temperature of the fruit and to prevent freezing if low temperatures are used to speed up the precooling.

In recent years precooling rooms holding up to 15 or even more car-loads of fruit per room have been built at shipside terminals. These rooms are constructed so that the circulating air moves in only one direction. The incoming chilled air enters the room at the ceiling

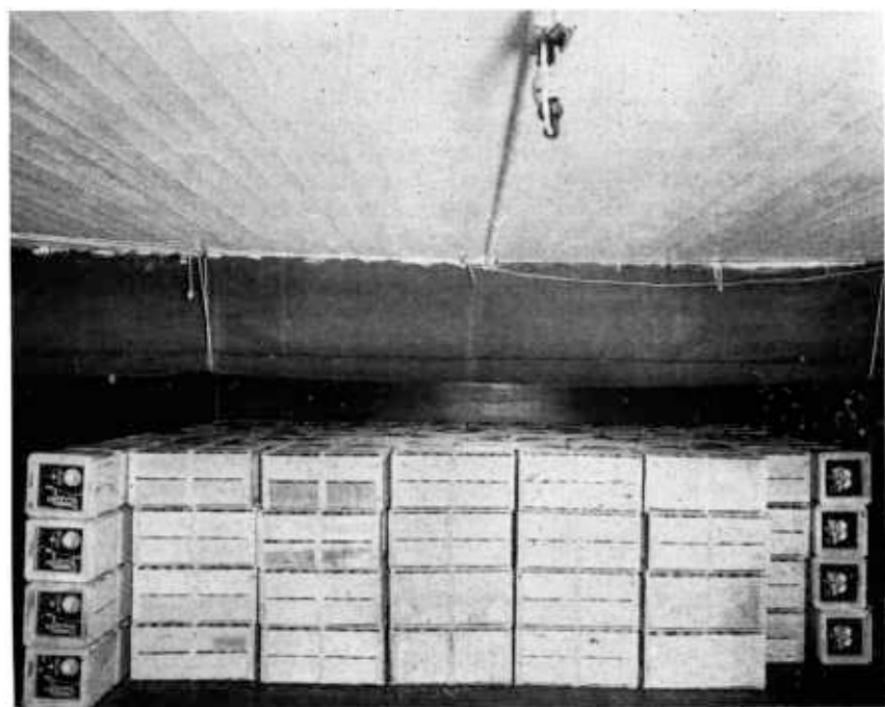


Figure 25.—Precooling room, showing method of stacking fruit and the canvas-curtain baffle that directs the air current, which is reversed periodically. Note the ample air space between the ceiling and the tops of the stacks of fruit. This is important for uniform rate of precooling in all parts of the room.

and is forced down through the load into a tunnel below the slatted floor for return to the bunker room.

In the blower room the air is cooled by means of brine-spray refrigeration, brine coils, or coils for direct expansion of ammonia. The brine-spray method is most commonly employed in Florida.

In the one-car precooling room the boxes of fruit are most conveniently stacked four high (fig. 25) and on their sides, so that they can be moved about with hand trucks. To get best results, the room should be almost completely filled and the air should be circulated at a rate of 4,000 to 5,000 cubic feet per minute. The temperature of the air blast should generally be held at 32° F. or slightly lower, and its

direction should be reversed every 30 minutes or every hour. This speeds up the precooling operation, reduces the danger of freezing the fruit located where the cold air enters the room, and facilitates a more nearly uniform cooling of the entire lot.

Ordinarily the average rate at which the temperature of wrapped fruit can be reduced after the first hour or two is about 2° or 3° per hour, but with adequate equipment nonwrapped fruit can be cooled even more rapidly. Nonwrapped fruit in wire-bound crates cools more rapidly than wrapped fruit in standard boxes, but when packed in cartons fruit cools very much more slowly. Precooling rooms must be watched carefully and the temperature of the fruit should be observed frequently to prevent damage, especially if the temperature of the air blast is lower than the freezing point of the fruit, which for oranges and grapefruit is about 28°.

Fruit exposed to the direct blast of the incoming air can be cooled to 36° F. or lower in a short time, but the bulk of the fruit in the room is cooled rather slowly. However, with good facilities the fruit can be precooled to a rather uniform temperature averaging 36° or below in less than 24 hours. This rate of precooling, which allows the same room to be refilled every day if desired, is of considerable importance during the rush season.

Although precooling rooms are not entirely satisfactory for the cold storage of fruit for a long period, they are sometimes used for this purpose, especially in assembling special orders for mixed lots or fruit of less common sizes. Fruit can, of course, be precooled in ordinary cold-storage rooms if these are available, but ordinarily they do not provide the desired uniformity or speed of cooling. Precooling in rooms with fans and built-in ice bunkers has been found satisfactory in other regions; it is economical when used only a few months during the year, and as compared with mechanical refrigeration it involves only a small initial investment.

In taking fruit temperatures the ordinary type of mercury or spirit thermometer with a pointed bulb easily inserted into the fruit is most commonly used. Usually temperatures are taken in a fruit in a box just inside the door of the room, where readings can be made most conveniently. Such readings, however, do not accurately indicate the temperature in the center of the stack; they are usually lower than that of the bulk of the fruit. Allowance has to be made for this in interpreting such temperature records. Electric resistance thermometers can be placed in different parts of the room and read in the office or elsewhere without the necessity of going into the room. This equipment has many advantages, but it is expensive and therefore is not commonly used.

In another method of precooling, a portable compressor is used, together with necessary expansion coils and a blower unit that is connected with the loaded car at its door. The cooled air from this unit is driven across the top of the load, filters downward, and is returned to the cooler through the bottom part of the doorway. Usually this type of precooling equipment is mounted on a motortruck so that it can be taken from place to place, but sometimes it is on heavy casters and is kept on the loading platform. Such equipment is reasonably satisfactory when an average temperature in the fifties or low sixties is desired, but these units cannot precool so fast as the room precoolers.

In still another method the precooling is also done after loading, with specially designed bunker fans, ice, and salt. The bunkers are filled with ice, and salt is added in amounts equaling about 3 percent by weight of the ice. A powerful but light fan driven by a $\frac{1}{4}$ -horsepower motor and delivering about 3,500 cubic feet of air per minute with 16- or 18-inch blades is attached on the inside of the car at the top of each bunker. The fan draws cold air from the ice bunkers, blows it over the top of the load, and forces it down through the load to the false floor, whence the air returns to the ice bunkers and enters through the bottom opening. Thus the normal flow of air in the car is reversed.

At the end of the precooling period, the fans are removed, the normal circulation is resumed, and the bunkers are replenished either by the shipper or at the first icing station. In precooling it is important to keep the bunkers filled with ice. Often too much ice is permitted to melt before the bunkers are replenished, and the effectiveness of the precooling is reduced.

Precooling the commodity after loading can also be accomplished with a fan system that is permanently installed under the floor racks of some railroad refrigerator cars. These fans can be operated for precooling by attaching a motor to the fan shaft on the outside. The fans force the air up through the ice-filled bunkers to the top of the load and thence down to the floor racks, the same as do the bunker fans just described.

After precooling, the motors are removed and the fans can be engaged with the car wheels by throwing a lever which causes the fans to operate when the car is in motion. The resulting air circulation equalizes temperatures and produces generally cooler temperatures than in ordinary cars, especially in the top of the load where they are needed most.

Precooling citrus after loading is not so efficient as the precooling that can be done in rooms, principally because sufficient time is rarely allowed to do the work. It is very difficult to reduce the commodity temperature to an average below about 50° F. within the time usually allowed with equipment now available. Even with this limitation, however, car precooling is generally worth while in bringing fruit below the range of temperatures that would be hazardous during shipment. Precooling, coupled with the judicious use of suitable protective services that can be had en route, is what shippers have to rely upon to deliver fruit to distant markets in good condition.

Although installation of permanent precooling facilities for citrus fruit is expensive and adds to the operating costs, it has proved to be a good investment, since precooled fruit, whether shipped with or without transit refrigeration, usually arrives at the market fresher in appearance and with less decay than nonprecooled fruit shipped under ventilation. The need for precooling is greater during the warmer months than during the cooler part of the season.

When shipments of precooled and nonprecooled fruit arrive at destination with nearly the same temperature, as sometimes happens, it should be kept in mind that it is not the temperature upon arrival that is important but rather how soon the temperature was reduced to a satisfactory level and whether it was maintained there afterward. In this respect precooled shipments always have the advantage.

TRANSPORTATION

The truck and the refrigerated steamship have entered the field of citrus transportation, once almost entirely in the hands of the railroads. Coastwise boat transportation was interrupted by wartime conditions, and interstate shipments by motortruck were reduced below prewar levels. It is interesting to note (table 4) that between 1930 and 1935, when general economic conditions were below normal, rail shipments fell off and boat shipments increased, whereas the maximum movement by truck was during the season 1948-49. Each of these three types of transportation has peculiar advantages.

RAILROAD TRANSPORTATION

Types of Cars

Although some fruit is shipped in ventilated boxcars in mild weather or for short hauls, most of the rail shipments are made in refrigerator

TABLE 4.—*Citrus shipments as fresh fruit from Florida and Texas, by crop years*

[1 3/4 bushels computed as 90 pounds (box) for oranges and tangerines and as 80 pounds (box) for grapefruit and limes]

Crop year	Rail		Boat		Truck	
	Florida	Texas	Florida	Texas	Florida	Texas
1919-20	1,000 boxes	1,000 boxes	1,000 boxes	1,000 boxes	1,000 boxes	1,000 boxes
1920-21	12,257	0	0	0	0	0
1921-22	13,401	0	55	0	0	0
1922-23	13,264	0	74	0	0	0
1923-24	16,852	0	2	0	0	0
1924-25	19,904	0	148	0	0	0
1925-26	17,443	0	245	0	0	0
1926-27	15,058	0	138	0	144	0
1927-28	16,139	269	161	0	499	25
1928-29	13,193	388	71	0	800	58
1929-30	23,083	638	253	0	1,500	91
1930-31	14,429	1,444	98	0	100	131
1931-32	26,713	955	611	0	2,880	201
1932-33	17,646	2,187	1,525	0	2,674	412
1933-34	16,366	1,110	4,012	0	2,984	355
1934-35	13,293	677	7,529	0	3,249	801
1935-36	10,631	1,749	9,461	0	4,276	1,061
1936-37	11,072	1,770	8,046	3	3,776	992
1937-38	16,967	6,955	9,365	73	3,466	1,868
1938-39	17,567	5,845	8,682	70	3,872	1,868
1939-40	22,578	6,781	11,297	234	6,877	3,917
1940-41	16,141	5,117	5,370	211	5,765	4,198
1941-42	19,422	4,079	7,107	59	7,854	5,519
1942-43	24,293	6,838	726	0	5,119	3,537
1943-44	37,206	10,029	0	0	3,325	1,849
1944-45	42,316	10,703	0	0	2,894	1,931
1945-46	33,535	15,086	0	0	2,099	1,951
1946-47	37,016	15,897	108	84	2,778	2,528
1947-48	35,680	14,738	2,036	760	4,506	3,320
1948-49	28,744	11,642	36	200	7,518	5,364
	27,101	4,468	17	218	16,923	8,636

cars. The hatches in these cars can be opened to ventilate the load if refrigeration is not desired.

End-bunker refrigerator cars, with minor modifications of design, have long been standard equipment. A few of these are double-deck cars, equipped with a supplementary floor rack that is hinged to the side walls about halfway between the floor and the ceiling. When placed in position for loading, this upper deck is about 3 feet above the floor of the car. This type of car is designed to reduce the damage from bruising and crushing of bagged fruit. When the upper deck is latched to the side walls, the car can be used as a conventional end-bunker car.

Another modification of the end-bunker car is a fan installed under the floor racks and connected with the car wheels so as to force air up through the ice bunkers and over the top of the load, as already described (p. 43). This gives very uniform and efficient refrigeration during transit.

Still another type of refrigerator car is equipped with overhead ice bunkers instead of end bunkers. Because of the location of the ice above the entire length of the load instead of at the ends, this car can carry a heavier load than the standard end-bunker car.

Transit Refrigeration

When precooled fruit is shipped, ice may or may not be placed in the bunkers, depending largely on weather conditions. In hot weather the bunkers are usually iced before the car is loaded, but ordinarily they are not re-iced in transit except when shipments are expected to be a long time en route; then one or more re-icings may be necessary. In cool weather bunker ice may be omitted and the cost of transit refrigeration saved.

Fruit loaded at ordinary temperature may be given standard refrigeration, initial icing, or merely ventilation. Standard refrigeration gives the best transit temperature because the bunkers are filled with ice before loading and are re-iced to capacity at all regular icing stations en route. The ice is sent from the storage room on a rail from which it is placed in the ice bunkers of the car. In standard end-bunker cars, however, even this service results in a rather slow reduction of commodity temperature in the top of the load where refrigeration is needed most; in fact, the reduction is so slow that it often fails to prevent the development of green mold rot in the top layer. Ordinarily 5 days or more is required to bring the temperature of the top-layer fruit to approximately 50° F. The cost of standard refrigeration varies with the length of haul and the number of re-icings.

Initial icing consists of filling the bunkers only once, usually before the car is loaded or at the first icing station thereafter. When the shipper does the initial icing instead of having it done by the railroad, he has to pay a bunker rental charge; but if he can buy the ice advantageously, the total cost is sometimes less.

With standard-ventilation service no ice is used, but the hatches are kept closed when the outside air temperature falls to 32° F. or below and are opened again when the air temperature rises above 32°. Shippers sometimes give special instructions regarding the manipulation of the vents. Since the greater part of the citrus crop of the Gulf States

is shipped during the cooler months and moves into progressively colder areas, it is possible to take advantage of the outside temperature in cooling the shipments as they move to northern markets and thereby save transit-refrigeration costs. Under some conditions it is possible to cool the load even more rapidly under standard ventilation than under standard refrigeration. When weather conditions in transit are such that the temperature of the fruit can be maintained within the range 34° to 50° by proper ventilation, that service is more economical than refrigeration and just as satisfactory.

Size and Types of Loads

In spite of the fact that there has been no great change in the size of the car, or in its refrigerating capacity, the minimum load for the conventional end-bunker car has been increased considerably. In 1915 the minimum load was 250 standard boxes; in 1920, 300; in 1928, 360; and in 1934, 400. In 1942, under wartime necessity, it was increased to the maximum capacity of most cars, ranging from 470 to 541 standard boxes and 505 to 525 wire-bound crates, depending upon the method of loading or the length of the car. With no increase in refrigerating capacity the increase in the size of the load meant a corresponding decrease in the amount of refrigeration furnished per box. This is a factor of considerable importance in the hazards of shipment, particularly as the height of the load is increased in standard end-bunker cars.

The ordinary load of citrus in 1 $\frac{3}{5}$ -bushel standard boxes is stowed in two layers on end; the third layer when used is placed lengthwise or crosswise on bottoms over the second layer. There are six or seven rows of boxes lengthwise of the car; if six, the first and second layers are stripped by nailing wooden strips to the crates to prevent lateral shifting (fig. 26, A). The seven-row load (fig. 26, B) is usually too tight to provide the vertical air channels between the rows of crates necessary for adequate cooling during the transit period. Another method of loading sometimes used is to place all boxes on their sides, but this is not generally employed although it saves the cost of stripping. The load should never be so high as to close off any part of the upper-bunker openings.

The 4 $\frac{1}{2}$ -bushel standard boxes are loaded in the same manner as the larger boxes, but the number of layers and rows is different. When they are loaded on end there are eight rows and three layers; when on their sides, there are eight rows and six layers (fig. 26, C).

The 1 $\frac{3}{5}$ -bushel wire-bound crates are never stripped. Usually they are loaded on their bottoms, lengthwise of the car, in seven rows of five layers each, which often do not extend completely from one side of the car to the other. To prevent lateral shifting, the alternate layers are started from opposite sides of the car. The second layer overlaps the spaces between the boxes in the first layer. This is the offset load (fig. 27), which has proved a very satisfactory method of loading so far as prevention of breakage is concerned. Too often, however, the crates are merely placed in the car without this loading arrangement (fig. 28, A) and considerable breakage results. There is no provision for air circulation in a car of wire-bound crates, since all channels through the load are blocked, and cooling is correspondingly difficult to accomplish.

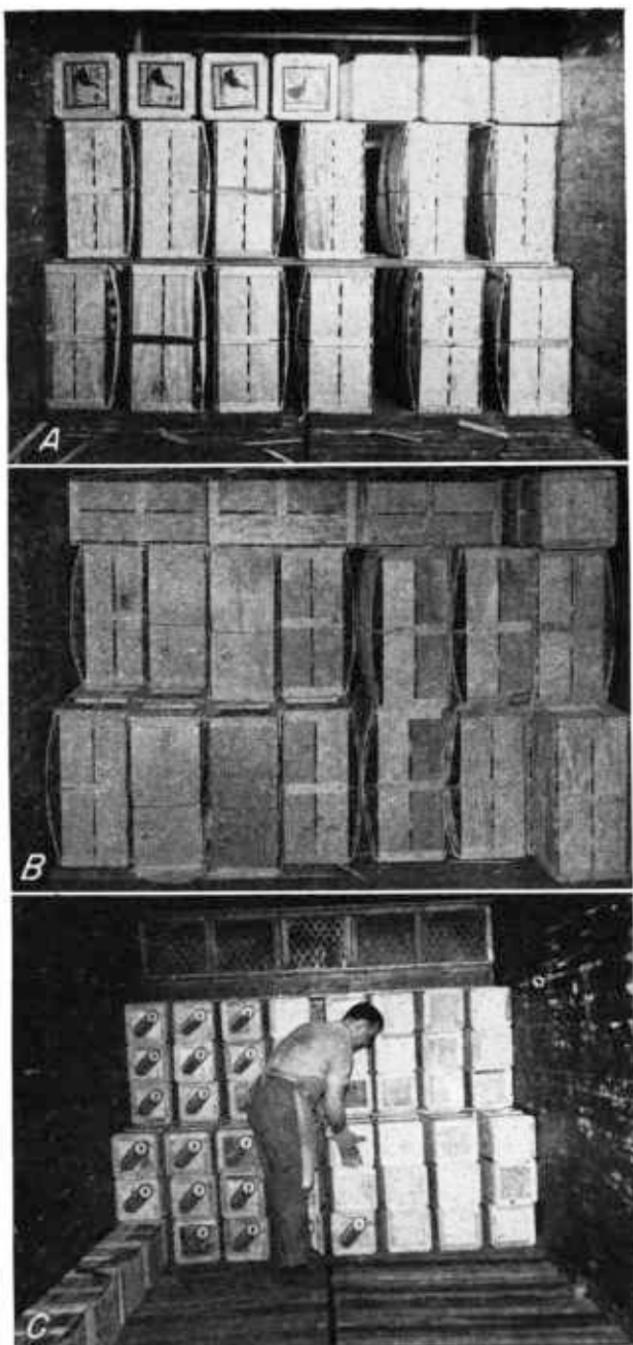


Figure 26.—*A*, Six-row stripped load. *B*, Seven-row nonstripped load. The stripped load is more expensive, but is generally regarded as more satisfactory. *C*, Four-fifths-bushel standard boxes being loaded on their sides. Such loads usually have only the third and sixth layers stripped.

The $4\frac{1}{2}$ -bushel wire-bound crates are loaded according to the same plan as the larger ones; the number of rows of crates as well as of layers, however, is different. Ordinarily there are eight rows and five or six layers of the smaller crates.

When cars are loaded with loose fruit in bulk or with open-mesh bags, the floors are padded with straw or excelsior pads to lessen the possibility of the weight of the fruit on top bruising the fruit below. Solid loads of mesh bags are satisfactory only in the early part of the shipping season of each variety, when the fruit is strong. When the fruit becomes dead ripe and tender, considerable crushing of the

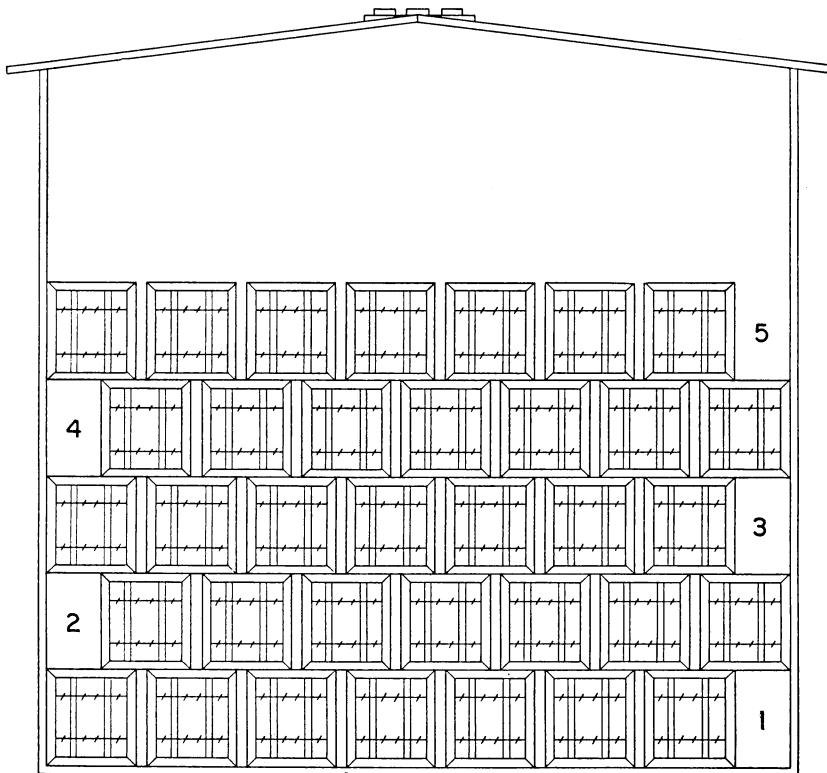


Figure 27.—The offset load in car loaded with $1\frac{3}{5}$ -bushel wire-bound crates. Whenever the car is wide enough to permit it, the offset load is preferred. The numbers indicate the layers.

fruit at the bottom of such loads should be expected. Bulk shipments are made only occasionally; usually they are confined to lower grade fruit or to consignments to nearby markets. The carrying quality of bulk shipments depends entirely upon the condition of the fruit when loaded, the kind of handling it receives, and the length of time it is in transit.

Many cars are loaded with both crated and bagged fruit (fig. 29). Ordinarily such loads consist of one or two layers (two when the fruit is fully ripe) of crated fruit, covered with a layer of padding, and of



Figure 28.—*A*, Car loaded with $1\frac{3}{5}$ -bushel wire-bound crates. Too often the crates are merely placed in the car, and considerable breakage results. *B*, Damaged crates of fruit in a car, a not-uncommon scene at a terminal market. Careless loading and unloading, as well as rough handling of cars during transit, contribute to crate breakage. The cost of such breakage ultimately falls on the grower.

bags on top of the crates. Because of the absence of vertical air channels, these loads do not cool well during transit.

The loads do not ordinarily fit the car's lengthwise dimensions exactly, and the slack is taken up by constructing a temporary end bulkhead made of 2- by 4-inch or 2- by 6-inch uprights and six 1- by 4-inch or 1- by 6-inch crosspieces placed at the bunker. For the smaller loads not permitted at present a center bulkhead may be placed in the doorway. These bulkheads prevent the load from shifting and breaking the crates. Mechanical squeezing devices for taking up slack so that the load in standard crates will be tight are ordinarily used in Florida and Texas, but they cannot be used safely on wire-bound crates.

Breakage of packed crates during handling and transportation is a matter of considerable importance. Some cars contain as many

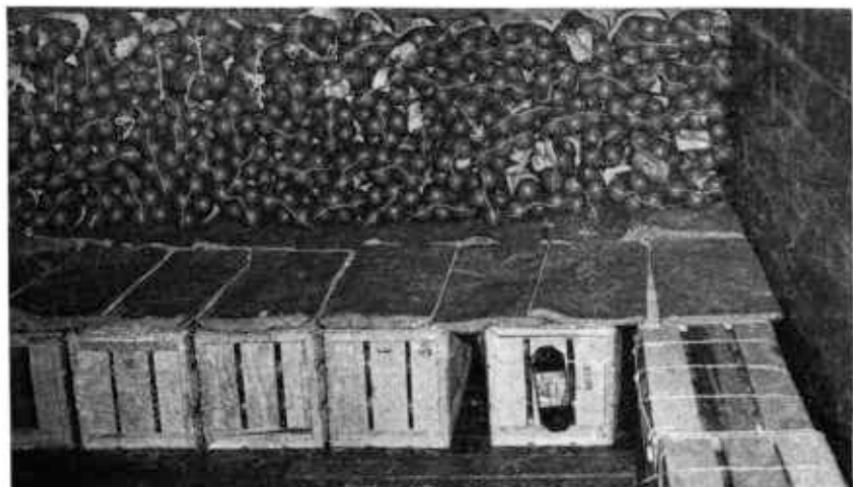


Figure 29.—A load of oranges consisting of bags over crates. Note the layer of excelsior pads separating the crates from the bags and protecting the bagged fruit from chafing by the crates. Unless properly spaced with an inch or two between pads, such a layer seriously interferes with air circulation and refrigeration during transit.

as 50 to 75 broken crates on arrival at market, but the general average is perhaps less than 2 percent (fig. 28, *B*). Some of this breakage occurs at time of loading when crates are flung into position or banged with a hatchet to take up slack. However, most of the breakage takes place during transit and unloading because of improper loading and rough handling or carelessness during unloading.

WATER TRANSPORTATION

Although ships have hauled Florida citrus fruits to market since the beginning of the industry, water transportation has assumed major importance only within recent years. An important factor in this growth of water transportation has been the good roads and fast trucks by which fruit can be moved easily and speedily to the various ports

of call. There it is received in large precooling or "cold holding" rooms pending the arrival of the ship. These facilities, together with cheaper carrying charges, have been largely responsible for the increased use of water transportation.

The principal disadvantages of water transportation are the limited number of markets that can be reached along the seaboard and the inability of the shipper to divert consignments.

Some ships are equipped to refrigerate the entire cargo, but others have only one or two refrigerated chambers. Nonrefrigerated chambers are usually ventilated by powerful blowers installed for this purpose. They are arranged so as to bring outside air into the fruit chambers as the inside air is expelled with the carbon dioxide and other products of respiration of the fruit.

One of the principal advantages of refrigerated ships is their ability to maintain the temperature of precooled fruit satisfactorily during transit. However, the refrigeration capacity usually is not sufficient to do much cooling of warm fruit. Therefore it is best to have the fruit precooled before loading, preferably at the loading point.

With modern facilities a ship can be loaded in less than a working day. Two or more holds can be loaded at the same time with an almost continuous flow of crates. The fruit can be loaded with a minimum amount of handling by using belts and other conveyors from the precooling or "cold holding" rooms to the ship's chambers. If the fruit is precooled, each chamber should be filled as completely as possible, the crates being stacked on their sides. If the fruit is not precooled, the refrigerating capacity is usually overtaxed if the chamber is filled.

MOTORTRUCK TRANSPORTATION

All-weather highways and the great number of trucks available have made the motortruck one of the most important means of transporting citrus fruits from producing areas and distributing centers to consuming districts. Truck transportation is preferred by many packing houses not only because it is more rapid but also because it is cheaper than rail or water shipment. The motortruck affords speed and flexibility of distribution not possible by any other means. By its use a shipper can quickly reach districts without direct rail lines and seaports. Three general types of service are rendered by trucks: (1) Transportation from the packing house direct to the receiver's place of business even in distant States; (2) transportation over more or less fixed routes, such as hauling fruit from the packing house to a distant rail or water shipping point or from distributing centers to merchants in nearby territory; and (3) transportation from points of production by peddlers, who conduct their own business in buying and selling the fruit.

Trucks are especially well suited for deliveries into nearby States away from the main rail lines, but they are also used for deliveries into Canada. All trucks can be ventilated, and some are equipped with ice bunkers and fans or mechanical refrigerating units to cool the load.

For short hauls an open truck is generally used. A tarpaulin should be placed over the load to protect it from rain, wind, and sun. For long hauls a van semitrailer is commonly used.

HANDLING EXPRESS SHIPMENTS

More than a million boxes of Florida citrus fruits are shipped annually by express from the grower or packer direct to the consumer. This business is seasonal and does not require a large financial investment. It is pleasant and profitable when properly handled. Many of the shipments are made by small operators who maintain dooryard packing plants located along main highways where motorists may stop for a glass of fresh citrus juice; while there they may purchase fruit to be expressed or carried to friends and relatives. Several types of packages are used in filling such orders, and frequently a few kumquats with leaves attached are included for decorative effect. Some customers prefer half a box of oranges and half a box of grapefruit or some other citrus fruit. A substantial portion of express shipments are made by city fruit-stand operators who solicit express orders. These are packed nearby, often with fruit grown in another part of the State.

Some of the large packing associations have express-order departments that specialize in the business; others merely pack and ship for individuals who solicit such orders.

For these individual shipments the fruit is handled in essentially the same manner and ordinarily is of the same quality as for carlot shipments that are forwarded from the commercial packing houses.

HANDLING FRUIT IN TERMINAL MARKETS

It frequently happens that railroad shipments of citrus fruit are held several days before being unloaded, sometimes as much as a week. In warm weather it is often necessary to have the cars re-iced, and in cold weather heater service may be required to protect the fruit from freezing.

Representative samples of the various lots to be sold at auction are displayed to prospective buyers. Buyers can also open up other packages and inspect them for decay, defects, and blemishes as well as the general condition of the fruit and pack. All of these factors are considered in bidding on the various lots. The value of all the precautions taken in handling and packing the fruit becomes evident at this time and is usually reflected in the sales price returned to the shipper. Rough handling in unloading, however, often nullifies the efforts of painstaking shippers to deliver their fruit in good condition. Rough and careless unloading methods cause breakage of containers and damage to the fruit that results in increased decay. Damaged crates may be repaired but usually sell at a discount.

Ordinarily the fruit is moved quickly from the auction buildings, or from cars on team tracks, to wholesale or retail stores. When the fruit goes first to a wholesale store and then to the retail stores, there may be enough delay to permit rot organisms to grow and for the fruit to lose freshness. The rate of deterioration is ordinarily in proportion to the temperature at which the fruit is held; the higher the temperature the faster the fruit deteriorates. The faster the movement of fruit through the markets the less the loss from aging effects and decay. This is important in warm weather, especially for merchants who are unable to hold the fruit in cold rooms.

HANDLING FRUIT IN THE HOME

Although citrus fruit is sometimes used for decorative purposes in the home, most of it is bought primarily for use as food and probably will be held several days or longer before being eaten. Citrus fruit not only loses its freshness of flavor and appearance very rapidly when held at the high temperature and low humidity of the average home, but also it is likely to decay, since the temperatures are favorable for the development of the principal rot-producing organisms. The consumer therefore should keep citrus fruit in the household refrigerator but away from the coldest parts of it. This will retard the development of stale flavors in the juice and greatly reduce the rate of decay. Green mold rot develops fully five to eight times as fast at room temperature as in the refrigerator, and stem-end rot will make practically no progress at all at 45° to 50° F., the range of temperature commonly maintained in refrigerators.

Ordinarily the citrus fruit can be kept in the refrigerator satisfactorily for as long as 2 weeks. But if diphenyl-treated wraps are on the fruit it should not be put in the refrigerator, because the odor will be taken up readily by butter and by salad dressing and even by some other foods.

CANNING AND OTHER PROCESSING PROCEDURES

An important adjunct to the citrus-fruit industry is the cannery and byproducts plant, which came into use about 1920. Although some of the processing plants are operated independently (without contractual affiliation with any grower or shipper), most of them are operated by fresh-fruit packing associations. These plants started out to serve as outlets for fruit of undesirable sizes or that which otherwise failed to meet the requirements of the fresh-fruit trade. They have grown steadily in both number and size because they have provided the trade with products so satisfactory that a large part of the more desirable portion of the crop is now being processed. Sometimes the crops from entire groves can be disposed of more profitably through the processing plants than through fresh-fruit channels. Table 5 shows data on the number of boxes of oranges and grapefruit processed annually in Florida and Texas since 1921.

Practically all of the stock going to the cannery is transported in bulk, usually in trucks with loads of about 27,000-pound capacity (fig. 30). For shipments by rail, boxcars are used.

Some of the fruit that goes to processing plants moves directly from the grove to the cannery. Some, especially that from small plantings, is hauled to roadside assembly bins and from there is transported to the cannery in huge trucks; but most of it comes from packing houses where the cannery stock is separated from that intended for the fresh-fruit market. Usually the third-grade fruit and the portion of the first- and second-grade fruit that cannot be marketed more profitably as fresh fruit are sent to the processing plant.

Most packing houses assemble their canning stock in large bins on the outside of the house. When bins are not used, the cannery stock is placed in field boxes and held until a truckload or carload has been assembled.

At the cannery the fruit is dumped onto conveyors and again placed in bins, usually by varieties. It then moves into the plant for

TABLE 5.—*Quantities of oranges and grapefruit entering cannery channels from Florida and Texas, by crop years*

[1% bushels computed as 90 pounds (box) for oranges and tangerines and as 80 pounds (box) for grapefruit and limes]

Crop year	Oranges		Grapefruit	
	Florida	Texas	Florida	Texas
	1,000 boxes	1,000 boxes	1,000 boxes	1,000 boxes
1921-22	0	0	9	0
1922-23	0	0	136	0
1923-24	0	0	181	0
1924-25	0	0	317	0
1925-26	0	0	362	0
1926-27	0	0	633	0
1927-28	0	0	543	0
1928-29	0	0	1,049	0
1929-30	0	0	1,640	20
1930-31	0	0	2,893	56
1931-32	36	0	933	103
1932-33	61	0	2,526	46
1933-34	56	0	2,369	86
1934-35	265	0	5,545	383
1935-36	213	0	3,646	619
1936-37	550	3	6,759	2,563
1937-38	1,109	1	6,157	5,203
1938-39	1,184	16	9,212	5,531
1939-40	4,270	15	8,812	6,900
1940-41	4,008	15	13,876	6,223
1941-42	4,271	20	10,143	6,118
1942-43	6,439	13	17,584	7,876
1943-44	11,011	43	20,446	8,322
1944-45	14,344	73	15,136	9,554
1945-46	19,220	360	22,136	10,562
1946-47	19,886	323	15,866	8,920
1947-48	30,421	299	19,451	8,661
1948-49	26,852	399	16,306	5,279

processing as hearts (sections, or pulp segments), as juice, or as concentrated juice (juice with part of the water removed by various processes), and byproducts such as dehydrated citrus pulp and molasses (both used for stock feed), citrus-rind oil, and pectin. The first step in the processing operation is washing the fruit and rejecting the unsuitable fruit.

Juice.—From the grading belt the fruit moves directly to machines which express the juice and channel it to large mixing vats; from there the juice is moved to sterilizers and thence to cans (fig. 31) and on to the lidding machines. From that point it passes through a cooler on its way to the packing machines. More than 33 million cases were put up in Florida during 1944-45.

Juice concentrate.—A pasteurized juice concentrate prepared by evaporation under vacuum was in heavy demand for overseas shipments during World War II. Since the war the preparation of a frozen concentrate has developed into a large commercial operation. This product is prepared by concentrating the juice to about one-

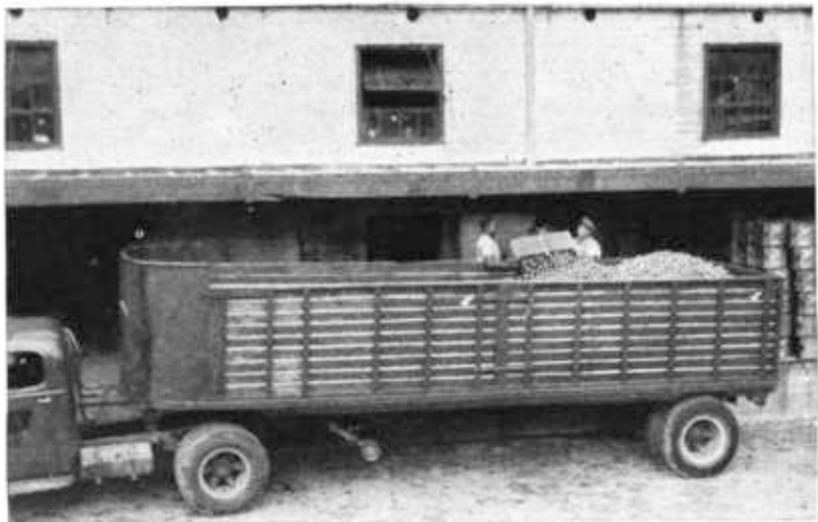


Figure 30.—Truck being loaded at packing house with fruit for the cannery.

fourth its original volume by high-vacuum low-temperature evaporation. The concentrate is canned, quickly frozen, and stored at sub-zero temperature. During the 1949-50 season more than 16 million boxes of oranges were processed into frozen concentrate.



Figure 31.—Sterilization of citrus juice before it is placed in cans, which are lidded promptly to prevent contamination.

Canned grapefruit hearts.—If grapefruit is to be sectionized, it is passed through a vat of hot water to facilitate the removal of the rind and the membrane. After the rind is removed by hand the fruit goes to workers who skin the sections and place them in cans (fig. 32). The filled cans pass to the lidding machine, thence to the sterilizer, and finally into the shipping package, usually a fiberboard carton. During the 1946-47 season and again in the 1947-48 season more than $3\frac{1}{2}$ million boxes of hearts including those of "salad" were put up in Florida.

Stock feed.—In making stock feed a small amount of lime is added to the refuse (seed, pulp, and peel), which is then ground and pressed



Figure 32.—Sectionizers preparing grapefruit hearts for canning.

to remove excess moisture. The pressed pulp passes through long rotating driers, which reduce the final moisture content below 10 percent. The pulp is bagged after being dried but while still hot. The output of stock feed, highly regarded as feed for dairy cows, is increasing annually with the growth of the processing industry.

Citrus molasses.—The liquid expressed from the pulp of citrus before it is dried contains about 8 percent of soluble solids that either go to waste or are evaporated in vacuum to a heavy brown syrup with a flavor more bitter than that of black molasses. This citrus molasses is used mostly in the preparation of mixed stock feeds.

Pectin.—The presence of relatively large amounts of pectin in the rind of citrus fruits and the fact that this jelling material can be

obtained so readily from citrus pulp have resulted in the establishment of a relatively new industry. The principal uses of pectin are in the preparation of jams and jellies and as a therapeutic agent.

Citrus-rind oil.—The outer rind of citrus fruits contains an essential oil that possesses considerable value as a flavoring material. Although the total volume produced is not great, orange oil in particular is in considerable demand.

HANDLING LIMES

The lime-producing industry is still comparatively young and small and is not highly organized. Two types of limes are grown: The small, round, yellow Key, or Mexican, lime and the larger, oblong, green Tahiti, or Persian, lime. The former thrives best on the Florida Keys, while the latter is adapted to the mainland. There has been little if any increase in the planting of Key limes in recent years, but during the same period rather extensive plantings of Tahiti limes have been made. Now the bulk of the crop is of the latter type.

Packing and handling methods are not so well standardized as those for the other commercial citrus fruits. The volume is not yet sufficient for a steady flow of carlot consignments. Therefore, the fruit is most commonly forwarded by truck; but sometimes it is shipped by express or by boat.

Limes are harvested and handled quite differently from oranges, tangerines, and grapefruit. Like the lemon, the lime tree in the warmer districts usually carries at the same time fruit of all ages from blossom to full maturity. Selection of fruit at any particular intermediate stage of maturity, therefore, is difficult and the limes are picked mainly according to rind texture and color. In harvesting, the lime is pulled from the tree rather than clipped. Because of the hot, humid climate where limes are grown, they must be handled expeditiously and with such precautions as can be taken in order to reduce losses from rots and rind break-downs of various types.

The Key lime is picked as its color changes from green to yellowish-green. If the fruit is picked before it reaches the yellowish-green stage, the juice sacs are not likely to be filled and there is a tendency for a dark rind scald to develop, giving the fruit an unattractive appearance that affects its selling price. If the fruit is left on the tree until it becomes yellow, it is likely to drop and be bruised. The yellow, overripe fruit is likely to develop a different type of rind scald along with a disagreeable flavor before it can be consumed. The factors that cause this trouble and methods of control are unknown.

When Key limes are picked at the right stage of maturity, the yellowish-green pigment in the rind gradually fades until the color is uniformly yellow. This may require only a few days at room temperature. The bulk of the crop is harvested during the summer months, the beginning of harvest depending on the earliness of the spring rains. Ordinarily this fruit is not given any special coloring or antiseptic treatment, and it is not packed by count. It is usually graded only according to size and condition.

The Tahiti lime is known to the trade as the green lime, because it has a green color when ripe and it retains this color during the marketing period. If it is picked too green, however, there is a deficiency of juice and a dark rind scald may develop. On the other hand, if the

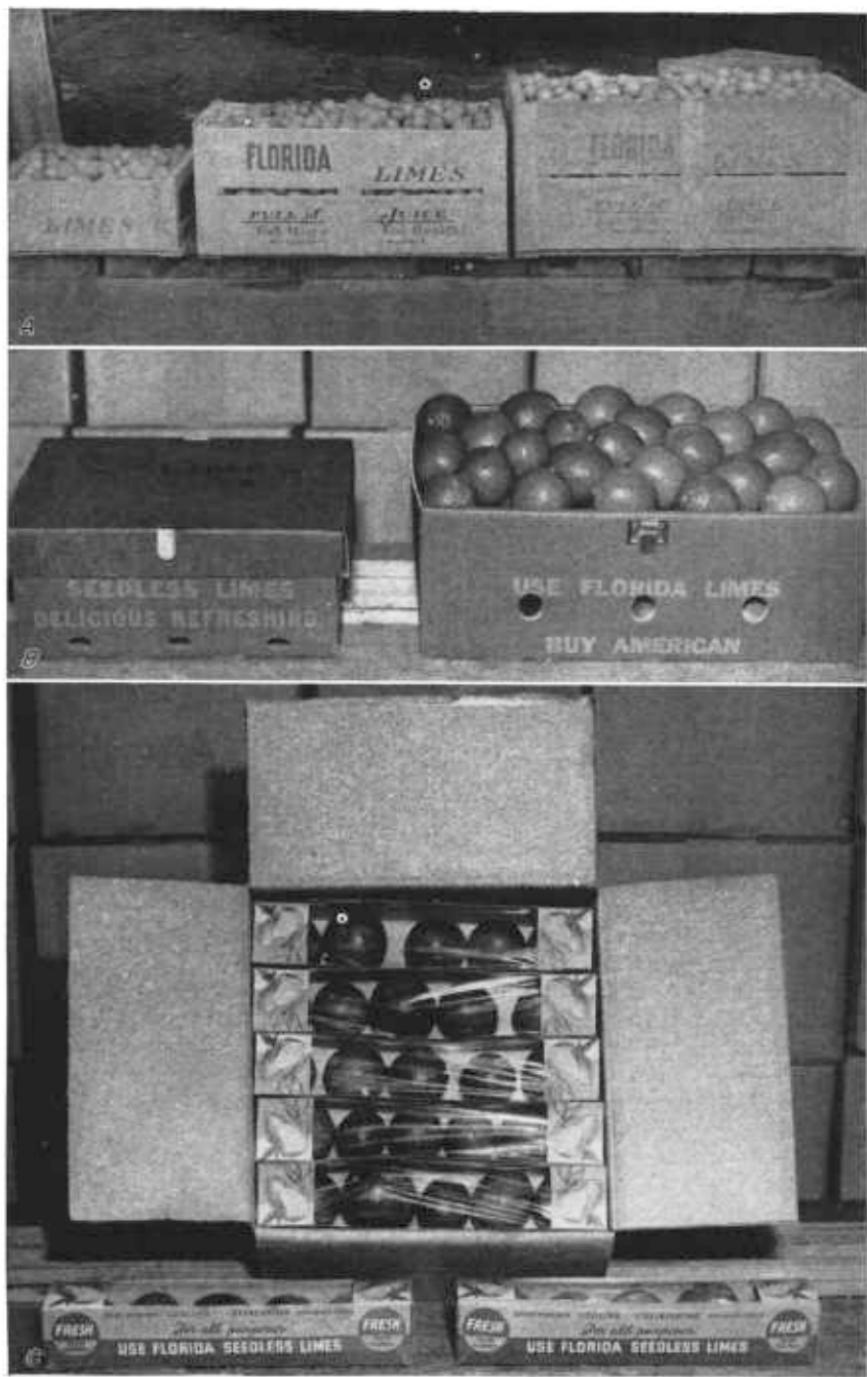


Figure 33.—Packages commonly used for Florida limes: A, The wooden crate, nailed or wire-bound, which is the most popular; B, the carton; C, the window package, holding five or six fruits. The last two are increasing in popularity.

fruit is left on the tree too long, or until it is almost ready to break color, a characteristic blossom-end scald accompanied by internal break-down terminating in decay and known as blossom-end rot may develop before it is picked or soon after. Lack of knowledge concerning this disease has been a serious handicap to the industry. Until recently the fruit was allowed to become mature before being harvested, but now it is harvested at an earlier stage of maturity and less trouble is experienced.

The optimum stage of maturity for harvesting is determined mainly by the general appearance of the fruit, especially the texture of the rind. As the fruit matures, the rind gradually loses its roughness and the juice content increases. The fruit is ready to be picked when it becomes comparatively smooth and slightly soft. The legal maturity standards adopted for limes, which are based mainly on juice volume, have brought about a more uniform product for the consumer.

The Tahiti fruit can be shipped every month of the year, but the bulk of the crop is harvested between May and November, with the heaviest movement during the summer months. No ethylene treatment is given, as the trade accepts the green-colored fruit in preference to that which has become partly or completely yellowed.

Few packing houses are equipped with machinery designed primarily for handling limes. Such machinery as is used is limited to polishing brushes, a wax applicator, a grading belt, and sizers. Equipment used for tangerines seems about equally well adapted to Tahiti limes.

Many types of packages are used for shipping limes. These range in size from the $1\frac{3}{5}$ -bushel crate to a consumer-size carton that holds half a dozen fruits. The cardboard containers of various sizes and the $\frac{4}{5}$ -bushel nailed or wire-bound crate are in most general use. Except in the smallest consumer packages, limes are jumble-packed and the approximate number of fruits, varying with size, is stamped on the container (fig. 33).

Limes can be stored satisfactorily for 6 to 8 weeks at temperatures of 45° to 48° F. and a relative humidity of 85 to 90 percent.

DECAYS AND THEIR CONTROL²

Citrus fruits are subject to various rots after harvest, depending upon the climatic conditions where the fruit is grown and the handling and storage methods used. The development of the organisms that cause decay is influenced greatly by the processes to which the fruit is subjected and the temperature and humidity after harvest as well as by the stage of maturity of the fruit. A brief description of the principal kinds of decay and of methods of control follows.

BLUE MOLD³ AND GREEN MOLD⁴ ROTs

Blue mold and green mold rots, or penicillium rots, of citrus (fig. 34) (sometimes called "pinhead rot," or "blister rot," terms descrip-

² For more detailed information on fungus rots, other diseases, and physiological disorders that affect market quality of citrus fruits, the reader is referred to Miscellaneous Publication No. 498, Market Diseases of Fruits and Vegetables: Citrus and Other Subtropical Fruits, which may be consulted in libraries or purchased from Superintendent of Documents, Government Printing Office, Washington 25, D. C., for 70 cents.

³ Caused by *Penicillium italicum* Wehm.

⁴ Caused by *Penicillium digitatum* Sacc.

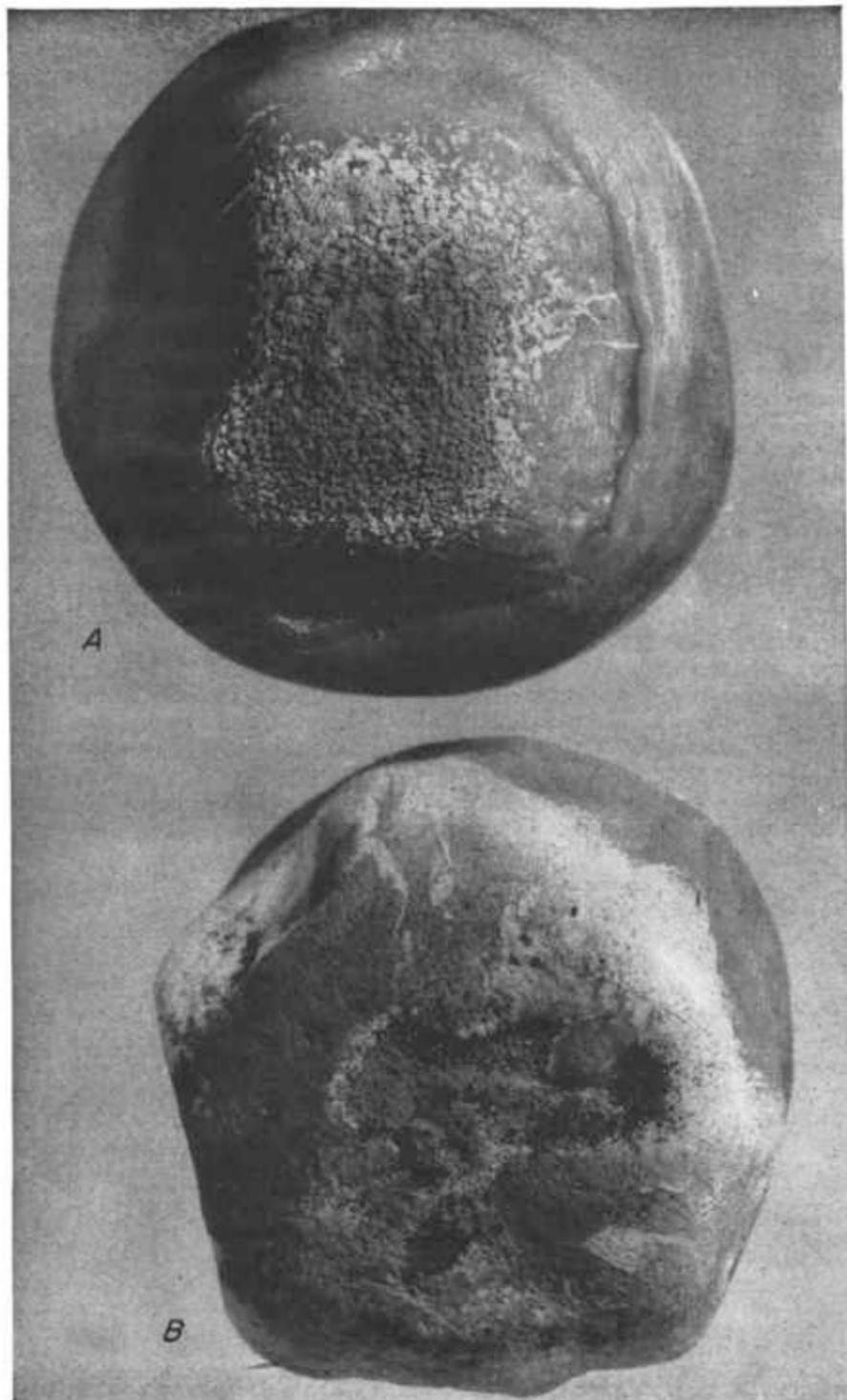


Figure 34.—Rots of grapefruit: A, Blue mold rot; B, blue and green mold rots.

tive of their early stages) are very widespread forms of decay during the winter months. The spores of the causal fungi are air-borne and are almost always present in all citrus-growing regions, but of course they are most abundant where decaying fruit is found. These rots occur for the most part during the cooler months or in fruit that has been held in cool or cold storage for some time. Temperatures between 65° and 80° F. are favorable for their rapid development, 75° being optimum for both; but the causal fungi, especially the blue mold, can grow slowly at storage temperatures as low as citrus fruits can stand.

The early stage of these rots is a small, soft, watery spot that gradually enlarges and becomes covered with scattered white fungus growth. Later these white specks coalesce into a velvety growth, which turns olive green or blue, depending upon which organism causes the rot. Spores of the green mold develop only on the surface, but those of the blue mold develop inside the fruit also. Sometimes both organisms occur in the same fruit. Green mold is by far the more common under ordinary conditions in the Gulf States, but blue mold is common on fruit that has been in cold storage for long periods.

Infection occurs for the most part through mechanical injuries such as clipper cuts and bruises. It may also occur while the fruit is on the tree, especially after cool, rainy periods. It is much more abundant during the winter months than in early fall or late spring or summer. Dead-ripe, early-bloom, or regular-bloom, midseason oranges and grapefruit are more likely to develop green mold rot in transit than late-bloom fruit of the same varieties or the fruit of late-ripening varieties handled at the same time. Blue mold also spreads by contact in packages. Under conditions favorable for the development of the causal fungi, the rots caused by them may develop seriously within 4 or 5 days—before the fruit reaches distant markets.

The first and foremost steps in preventing blue and green mold rots are careful handling at all stages to prevent mechanical injury of the fruit and general sanitation in the packing house to reduce the sources of infection. Antiseptic dips such as 5-percent borax solution, as described on page 21, are effective in reducing losses from these rots. For best results this antiseptic treatment should be given within 6 or 8 hours after the fruit is picked.

Sodium ortho-phenylphenate applied in conjunction with wax emulsion (p. 22), diphenyl-impregnated fruit wraps (p. 66), diphenyl-impregnated case liners, and diphenyl-treated separators between the layers of fruit in the shipping box are all effective in checking penicillium rots.

Refrigeration promptly applied to reduce the temperature of the fruit to 38° F. or below is most effective in reducing losses; but at a temperature of 50°, which is about the average temperature of fruit under refrigeration during transit, the rate of decay is greater, about 30 to 35 percent of that at 70°.

Fruit that has been subjected to the high temperature required in the degreening treatment is very much less susceptible to penicillium rots than similar fruit held at ordinary air temperatures. The reason is that the temperature is too high for the causal organisms; it is, however, particularly favorable to those causing stem-end rot.

Stem-end rot (fig. 35) is less widespread than the penicillium rots, but in the Gulf-coast region it probably causes greater financial losses. It is a serious problem in all varieties in Florida and in the West Indies, where the climate is humid, but thus far it has been less important in Texas. Temple oranges and navel oranges are often seriously affected with stem-end rot in Texas; other oranges and grapefruit are attacked less commonly, but under certain weather conditions they may be seriously affected.

Stem-end rot is characterized by a softening and decay of the rind and pulp tissue in the stem area; in its early stages it can be confused with penicillium rots. There is frequently an indefinite demarcation



Figure 35.—Stem-end rot of Valencia orange.

between normal and affected tissue, but often there is little if any discoloration of the affected parts. When discoloration occurs it is of a buff to a somewhat darker shade. The decay may advance rapidly through the core, often reaching the blossom end before more than a third of the rind has been invaded.

Stem-end rot is caused by two fungi, *Diplodia natalensis* and *Phomopsis citri*. Frequently both occur in the same fruit. The symptoms caused by these organisms are very much alike. The rot caused by *Diplodia* is favored by high temperature and occurs most frequently during the warmer, humid months. The rot caused by *Phomopsis* develops best at a somewhat lower temperature and pre-

⁵ Caused by *Phomopsis citri* Fawc. and *Diplodia natalensis* Pole-Evans.

dominates in winter and early spring. The most favorable temperature for the development of *Diplodia* is about 86° F. At 50° its development is very effectively checked. The most favorable temperature for the development of *Phomopsis* is about 73°. Its growth is greatly retarded at 50°, but it can continue to grow very slowly in fully ripe fruit at 38°. Fruit subjected to the degreening treatment is especially likely to become affected with stem-end rot, usually the form caused by *Diplodia*; however, the form caused by *Phomopsis* is also increased. The fruit becomes progressively more susceptible to rapid development of stem-end rot as it becomes more mature.

For practical purposes it may be considered that all infections by fungi that cause stem-end rot occur while the fruit is on the tree and that they remain in an incipient stage in or on the stem or stem parts until after the fruit is harvested. Under favorable conditions the rot then develops rapidly and can cause heavy losses within 10 days to 2 weeks after harvest. Since several days is required for the organism to advance from the stem into the fruit, the loss of the stem parts during the washing and polishing operations makes it less likely that the fruit will develop stem-end rot than if the stem parts adhere. Treating the fruit with a 5- or 8-percent borax solution (p. 21) when it arrives at the packing house is effective in checking stem-end rot, but if the application is delayed until after degreening its effectiveness is greatly reduced. A weak solution of sodium ortho-phenylphenate applied in conjunction with the usual wax emulsion (p. 22) is also effective. So is the use of diphenyl as described on page 66. Careful operation of the coloring rooms, packing the fruit as soon as possible, and placing it under refrigeration immediately thereafter so as to promptly reduce the pulp temperature to 50° F. or below are all important steps in reducing possible losses, especially during warm weather.

ANTHRACNOSE⁶

Anthracnose, or *colletotrichum* rot, of citrus fruits is usually of minor importance, but occasionally it may become troublesome during storage of a weakened crop. *Colletotrichum* can attack the fruit at any point, but the principal region affected is the stem area, in which it produces a rot that may be confused with other rots that occur at the stem end. However, at ordinary temperatures anthracnose develops more slowly than the other rots. The fingerlike patterns, so common in the usual rot at the stem end, are also occasionally observed in anthracnose. With anthracnose there is usually a more definite margin between the normal and the affected parts. Ordinarily the latter are slightly sunken especially around the stem and darkened, and the affected part of the rind and the core becomes dark olive to black, fading into a pinkish to normal cast toward the periphery of the affected parts.

The disease has not been controlled with antiseptics; in fact the use of borax and stronger chemicals has seemed to increase the susceptibility of the fruit. Refrigeration is the most effective known means of retarding development of anthracnose.

⁶ Caused by *Colletotrichum gloeosporioides* Penz.

BLACK ROT (ALTERNARIA ROT)⁷

Black rot occurs very commonly but is rarely serious. Oranges are more susceptible than other kinds of citrus fruit. The disease is not always easily detected by casual examination. Early in the season, before the green color is lost, infected fruits have a pinkish discoloration around the blossom end or that portion assumes an orange color prematurely. Later, when the remainder of the fruit assumes the normal color of maturity, this symptom disappears. With varieties other than navels often the only outward symptom is a slight lesion across the stylar scar, so inconspicuous that it can hardly be detected by the graders; but in a large percentage of these cases the rind tissue and the core close to the blossom end may be dark gray or black. The affected area enlarges very slowly, and very little of the flesh decays except in extreme cases. Navel oranges seem to be most subject to this disease. No special remedial measures have been developed. Black rot, however, is known to be least prevalent on trees that are kept in a healthy condition.

ANTISEPTIC TREATMENTS

Antiseptic treatments have long been employed for checking decay in citrus fruits, but the use of only materials that involve no hazard to health is permitted. The application of these harmless materials is often so modified to suit the convenience of the operator that their effectiveness is greatly reduced.

Borax is the cheapest and most generally used substance. The best time to apply mild antiseptics of the soluble borate type is as soon as possible after the fruit is harvested. If the application is delayed even overnight, its efficacy against penicillium rots is considerably reduced and it is not likely to be so effective against stem-end rot. Borax is more effective against the type of stem-end rot caused by *Diplodia* than against that caused by *Phomopsis*; boric acid, however, is more effective against that caused by *Phomopsis* than against that caused by *Diplodia*. This difference may explain some of the inconsistent results obtained by the use of these materials. The particular one used will depend on the organism likely to be most prevalent at the time. For best results the borate should be left on the fruit several hours before the fruit is rinsed. Cost and safety considered, an application of borax made as soon as the fruit reaches the packing house, whether the fruit needs degreening or not, is the most effective antiseptic treatment that can be recommended.

In warm weather a momentary dip in the borax solution is as effective as immersion continuing for several minutes, but in cold weather longer immersion is necessary. Since this bath must be kept at temperatures around 100° to 110° F. to maintain the proper concentration of borax in solution, provision must be made to heat the solution.

The relative insolubility of borax is a disadvantage that can be partially overcome by using a mixture of 2 parts of borax to 1 part of boric acid. Such a mixture is considerably more soluble than

⁷ Caused by *Alternaria citri* Ell. and Pierce; not uncommonly *Colletotrichum* sp. is recovered from the affected parts.

borax, but it is more likely to injure fruit which has barely reached legal maturity. Some heat is needed to keep this mixture in solution.

Sodium metaborate is about as effective as borax and is more soluble. No heat is needed to keep it in solution, even in winter. However, this material is so alkaline that treated fruit may develop a brown, sunken discoloration around the stem after weeks of storage. Anthracnose (*colletotrichum rot*) (p. 63) often follows this injury.

Several machines have been devised for giving the borax treatment on the receiving platform. The fruit is emptied at one end of the platform and is passed through a vat containing a 5- to 8-percent borax solution⁸ heated to about 110° F., necessary to keep the borax in solution. Generally a conveyor belt is used to carry the fruit out of the vat; then the fruit is replaced in field boxes before it goes to the coloring rooms.

A simple hand-operated device, adapted to the needs of the small operator, can be used for rapidly dipping both the field box and its contents. Its principal advantages are its simplicity and low cost; its principal disadvantage is that the field box as well as the fruit is wetted and thereby the drying problem is greater. In cold weather some means of heating the borax solution must be provided to prevent the chemical from being partially thrown out of solution by the cold fruit.

An important factor in the effectiveness of the treatment, particularly against stem-end rot, is the rate of drying of the borax solution. Ordinarily, better rot control is obtained when the borate material is left on the fruit for several hours.

Because of the extra handling required, the application of borates on the platform is not now in general use. A less effective but more convenient method of application is more generally used. It consists of passing the fruit through a borax tank, located between the washer and drier. A light spray of water is played on the fruit after it emerges from the tank, to remove the adhering borax. This method of treatment is generally of little or no benefit against stem-end rot, because of the short time the fruit is subjected to the treatment, but it is fairly effective against green mold rot.

Sodium ortho-phenylphenate is quick acting and effective, but not so safe for the fruit as borax. It can be applied in a wax emulsion (fig. 36) just before the fruit is packed. It is important that this material be flooded on or the fruit dipped (figs. 10 and 36) to assure thorough coverage. The concentration of the mixture should not exceed 1 to 1 1/4 percent or be less than 3/4 percent and the treatment should be given at room temperature. The addition of 1 part of formaldehyde to each 4 1/2 parts of sodium ortho-phenylphenate lessens the danger of rind injury but does not eliminate it. After every three or four carloads have been treated one-fourth of a normal charge of the antiseptic and wax should be added to keep the tank solution at full strength. Rind injury sometimes caused by this material manifests itself as small, reddish splotches that may not develop until 10

⁸ The desired concentration can be ascertained by a Brix hydrometer. This instrument, which is used in measuring total soluble solids in citrus juices, is available in most packing houses. When the temperature of the solution is between 100° and 110° F., the concentration indicated is close enough for practical purposes.

to 15 days after treatment. Ordinarily these splotches are of no commercial significance.

Diphenyl, which is more effective against stem-end rot than against green mold rot, has been in limited use for several years. It is insoluble in water and can best be used in wrapping tissue, box or bag liners, and separator sheets between layers of fruit. Pulverized diphenyl sprinkled in kraft bags at the time of packaging has proved effective also. Since diphenyl is volatile, the greater the amount that is used, within reasonable limits, per crate of fruit the longer its effectiveness is. Between $\frac{1}{4}$ and $\frac{1}{3}$ of an ounce per crate of fruit is close to the minimum effective dose. It volatilizes slowly, giving off pungent fumes that arrest decay of wrapped fruits. When the diphenyl odor disappears, the rot-producing fungi resume growth and decay may set in. Because of its pungent odor and its liability

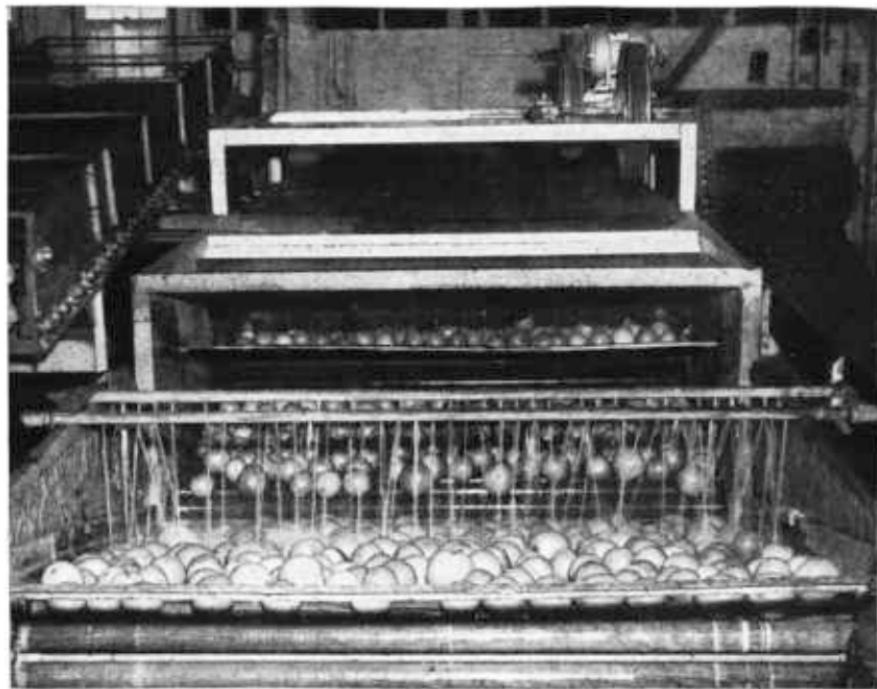


Figure 36.—Flooding on an antiseptic incorporated in wax emulsion, a satisfactory method of application.

to affect the flavor of butter and of some other foodstuffs, diphenyl is not popular for treating consumer packages that may find their way into apartments or into household refrigerators where an assortment of foods capable of absorbing the odor may be stored.

There are other materials more effective in checking decay than those already mentioned, but for various reasons their use cannot be recommended. At best decay reduction is all that can be expected from the use of antiseptics. They do not preserve the fresh-from-the-tree flavor or appearance. Use of refrigeration all the way from packer to consumer is much more desirable from the standpoint of preserving the tree-fresh flavor and appearance of the fruit.

PHYSIOLOGICAL DISORDERS

AGING

"Aging" is the name used for the condition sometimes found after harvest on citrus fruit, chiefly oranges and grapefruit, in which the rind around the stem button or elsewhere on the upper part of the fruit becomes wilted or shriveled. This condition is apparently caused by loss of water from the fruit. It is frequently accompanied by a browning of the affected areas and collapse of the oil glands. Browning, however, may be caused by improper conditions in the coloring room or by the use of heated solutions in washing the fruit in the color-added process.

Fruits showing extreme symptoms of aging, accompanied by browning, usually have an off-flavor or aged flavor.

Measures that help to prevent aging are picking fruit before it is overmature, avoiding overheating in packing-house treatments, and storing for limited periods only at fairly high relative humidity (85 to 90 percent). Limes should be stored at 45° F. or slightly higher.

WATERY BREAK-DOWN

Watery break-down is a soft, spongy condition of the entire fruit that develops after prolonged storage at temperatures below 40° F. It resembles freezing injury. Affected fruits have a pronounced objectionable flavor and are completely waterlogged.

FREEZING INJURY

Fruits frozen in the field are found scattered through boxes. Transit and storage freezing, however, is worse in exposed fruits in the bottom-layer boxes or in those nearest cooling coils. Affected fruits may show water-soaked areas in the rind. Internal tissue is disorganized, water-soaked, and milky and has a rind flavor. Frozen fruits lose moisture; this loss causes drying, separation of juice vesicles, and buckling of segment walls.

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